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REPORT

OF THE

DEPARTMENTAL COMMITTEE

APPOINTED BY THE

PRESIDENT OF THE LOCAL GOVERNMENT BOARD

TO INQUIRE AND REPORT WITH REGARD TO THE USE OF

INTERCEPTING TRAPS
IN HOUSE DRAINS.

Presented to both Houses of Parliament by Command of His Majesty.

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MINUTE OF APPOINTMENT.

I hereby appoint—

Ludovic William Darra Mair, Esq., M.D.,
Allan Arthur Grenville Malet, Esq., M.Inst.C.E.,
and
Harry John Pearson, Esq., A.R.I.B.A.,

To be a Committee to inquire and report with regard to the use of intercepting traps in house drains.

And I hereby appoint the said Ludovic William Darra Mair to be Chairman and Edward Hardwick Terry, Esq., to be Secretary of the said Committee.

(Signed) JOHN BURNS,
President of the Local Government Board.

Whitehall,
15*th October*, 1908.

DEPARTMENTAL COMMITTEE ON INTERCEPTING TRAPS IN HOUSE DRAINS.

REPORT.

TO THE RIGHT HON. JOHN BURNS, M.P.,
PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

SIR,—We, the Committee appointed by you to inquire and report with regard to the use of intercepting traps in house drains, have the honour to present our report.

Introductory.

1. This investigation nominally originated with a proposal, by the Willesden Urban District Council, to adopt a series of building bye-laws, in which the requirement as to the provision of an intercepting trap was to be omitted. The Local Government Board refused their assent to this proposal, but promised that it should be made the subject of a general inquiry, and in due course, Mr. Brook Kitchin, Dr. Darra Mair and Mr. Malet were deputed, as representing the Architectural, Medical, and Engineering departments, respectively, of the Board, to carry it out.

2. Soon after the commencement of this joint inquiry, it became evident that in consequence of conditions found in intercepting traps in Willesden, which will be referred to later, an extensive examination of such traps in other districts would be necessary. Accordingly, the assistance of a large number of local authorities of districts near London, where much building under modern conditions has taken place, was invoked, and we wish to express our thanks to them and their officers for the valuable information which resulted. Twelve months elapsed before these local examinations were completed, and at this stage it was deemed necessary, in consequence of the growth of the investigation, to convert the joint inquiry into an inquiry by Departmental Committee. In this Committee, Mr. Pearson took the place of Mr. Brook Kitchin.

3. It was contemplated that we should visit a number of towns and districts in England and Wales, where conditions illustrative of the advantages and disadvantages of the intercepting trap might be found, but, after consideration, it appeared to us that it would be more satisfactory and less costly to examine representative witnesses in London, and subsequently to make local investigations and experiments. We issued a circular letter, therefore, to the local authorities of the Metropolis and of the large towns, inviting statements from their expert officers in regard to the main points at issue. We also communicated with various gentlemen of recognised experience in drainage questions; with certain others who had been engaged in special research and investigation in regard to sewer air and drain air; and with the Royal Institute of British Architects, the Architectural Association, the Royal Sanitary Institute, and the Institution of Civil Engineers.

4. The responses to these communications were very numerous. They comprised many valuable contributions, and we desire to thank all those who assisted us in this way. From them we were enabled to select witnesses to give evidence before us, the main consideration, which influenced us in this respect, being the necessity of obtaining facts bearing on the questions at issue. A list of the witnesses who were good enough to give evidence is in Appendix I., and we desire to record here our hearty thanks to these gentlemen for their assistance in explaining to us their views, experience, and the results of their investigations.

5. Since hearing evidence we have also studied a large number of valuable and interesting experiments, the results of which have amply justified the large amount of time which was necessarily expended on them and which, indeed, has been one of the chief reasons why we have not been able to present our report at an earlier date. The experiments were conducted and carried out by Mr. Steele, then the deputy Engineer to the Bristol Corporation (now Engineer to the Corporation of Newcastle-on-Tyne), in connection with the effect on traps of sewer air and drain air under pressure; by Mr. Patten Barber, Engineer to the Borough Council of Islington, in connection with the passage of sewage through various intercepting traps; and by Dr. F. W. Andrewes, Pathologist to St. Bartholomew's Hospital, in connection with the convection of sewage microbes from sewers to drains, under practical conditions. The last-mentioned experiments were carried out at East Grinstead with the assistance of Dr. Wallis, Medical Officer of Health, and Mr. Woollam, Surveyor, and at Willesden with the assistance of Dr. Butler, Medical Officer of Health and Mr. Woods, chief Sanitary Inspector.

We cannot speak too highly of the skilful and laborious work accomplished by all those who carried out these experiments, and of the care and trouble taken by those who assisted, to ensure their success, and our most cordial thanks are due to them. At the same time we also wish to thank the Councils of the city of Bristol, the borough of Islington, and the urban districts of Willesden and East Grinstead, for the opportunity they afforded of conducting these experiments in their respective districts.

General Considerations.

6. The controversy regarding the necessity and usefulness of the intercepting trap in house drains is one of very long standing, and has led to much conflict of opinion among sanitarians both in this country and abroad.

Those who favour the trap claim that, in order to prevent escape of sewer air into the dwelling and injury to the health of the occupants likely to be caused thereby, it is essential to interrupt the aërial connection between public sewer and private house drain, and that, if this involves disadvantages, they are largely matters of detail capable of remedy; also that, even if some of these disadvantages are irremediable, they must be endured in view of the supreme necessity of excluding sewer air from the drain. On the other hand, opponents of the trap, while agreeing that sewer air should not be allowed to escape into the dwelling, contend not only that the intercepting trap is not an effective or a necessary instrument for this purpose, but that, in addition, the disadvantages it brings in its train are serious.

7. In the first attempts to control the construction of house drains by bye-laws in this country, it appears to have been accepted that house drains should be used for ventilating the sewer with which they were connected. But in 1877, when the Local Government Board issued one of their earliest series of model building bye-laws, this principle was abandoned, and a clause was inserted requiring an intercepting trap to be placed between the sewer and house drain in order, expressly, to prevent the entry of sewer air into the house drain. The reason for this alteration arose from the belief, then almost universal among sanitarians, that sewer air was one of the most, if not the most direct and commonplace way of all, by which certain infectious diseases were disseminated.

8. Dr. Parsons, recently Assistant Medical Officer of the Local Government Board, informed us that it has since been the practice of the Board, when proposed bye-laws have come before them for sanction, to urge local authorities to retain the clause requiring the provision of an intercepting trap, and that until this inquiry commenced, its omission had not been accepted by the Board, except in the case of short drains to which no indoor water-closet is attached. The question therefore is whether this practice of over 30 years ought to be continued or whether it may, with safety, be abandoned or modified. This obviously involves very careful consideration, not only of the available evidence, bearing on the influence on health of emanations from sewers and drains, and of the bacteriology of sewer air and drain air, but also investigation of the practical working of the intercepting trap, and of the disadvantages alleged against it, as compared with the advantages claimed for it.

PART I.

DISADVANTAGES OF THE INTERCEPTING TRAP.

9. The alleged disadvantages of the intercepting trap fall into four groups. One is that it forms an obstacle to the passage of air from the sewer through the house drains and the ventilating shafts thereof to the external air, and that consequently the ventilation of sewers is rendered both difficult and costly. As this alleged disadvantage is claimed by those who favour the trap to be its chief advantage, we do not propose to discuss it at this stage, though we refer to it later on (pars. 118–124).

Another disadvantage urged by many is that the trap involves separate ventilation of the house drains, and that this necessitates the provision of a fresh air-inlet to the drain, which, owing to the capricious nature of air currents, often acts as an outlet for foul air, and becomes a nuisance.

A third objection is that the intercepting trap complicates and enhances the cost of the construction of house drains, not only by reason of addition of the trap itself, but also from the necessity of providing the air-inlet to the drain, proper means of access to the trap, and in other ways.

Lastly, the trap is objected to on the ground that it forms a serious impediment to the passage of sewage from the house drain to the sewer, and that this frequently results in more or less complete blockage of the drain.

The Fresh Air-inlet.

10. The model bye-laws require the provision of two untrapped openings in a house drain, for the purpose of securing its free ventilation; one to act as inlet for fresh air, to be placed at or near the ground level; the other, to be placed as far as possible from the former opening and at a sufficient height, to act as a safe "outlet for foul air." Usually the air-inlet is in front of the house on the house side of the intercepting trap, and the outlet pipe is at the back of the house, but this arrangement may be reversed; usually, also, the outlet pipe is the soil pipe, but it may be an independent ventilating shaft.

With few exceptions, the evidence before us was unanimous that the air-inlet is an objectionable feature of the house drainage system. When it is level with the ground, not only may nuisance arise from its action as an outlet for smell, but it is frequently itself responsible for blockage of the intercepting trap, for in this position it serves as a surface gulley and admits of the passage of earth and other detritus from the surface into the trap.

In order to obviate these disadvantages, the air-inlet is frequently raised above the level of the ground, and its opening provided with a light mica flap with a view to prevent its action as an outlet for foul air. This arrangement, however, is often unsatisfactory. The mica flap and its attachments are perishable, and sooner or later the flap is broken off and disappears. Moreover, if the air-inlet is not much above the level of the ground, it is easily tampered with and blocked, either mischievously or deliberately, while if it is placed higher so as to be out of reach, this may involve proximity to windows, where it is liable to be a source of offensive smell, perceptible inside as well as outside the house.

It was urged by some witnesses that the air-inlet should be continued to or above the level of the roof. This would, no doubt, overcome the above disadvantages, and bye-laws requiring such elevated air-inlets have been sanctioned by the Board in some cases. But there are obvious objections to a requirement of this kind. Several witnesses contended that it would be impracticable to enforce it generally, for not only does it add materially to the cost of drain construction, but the provision of such a pipe on the front of the house, projecting above the eaves, is very strongly objected to on the ground of unsightliness.

11. Dr. Butler suggested that the escape of drain air from air-inlets may be not only a source of smell, but also a cause of disease. He has found that, in the Willesden urban district, diphtheria has prevailed more, over series of years, in areas where the intercepting trap is universal, that is in the most recently built parts of the district, than in the older and more congested areas where the trap is absent. He pointed out also that the incidence of diphtheria in the district, when spotted out for a number of years on a map, presented a distribution very similar to that of

blocked intercepting traps and displaced raking arm stoppers which had been discovered as a result of his systematic observations of inspection chambers in the district, to be referred to presently. In this respect diphtheria differed materially from scarlet fever, the distribution of the latter bearing no sort of relation to that of blocked intercepting traps. Although the evidence was inconclusive, as Dr. Butler himself admitted, he was inclined to attribute the observed difference of incidence of this disease to the existence of air-inlets, permitting escape of drain air, in the newer areas, and to their absence in the older.

12. It has been generally assumed that a fresh air-inlet is essential when there is an intercepting trap, but it is not clear that this assumption is correct. A number of experiments carried out at Bristol by Mr. Steele on the drains of two adjoining houses, one of which had an intercepting trap and the other had not, indicated that it is not necessary to secure the passage of currents of air through a drain, in order to prevent pressure on the house traps, and that the air-inlet, as such, may probably be dispensed with, without practical disadvantage (Appendix III., Experiments K, pp. 54-58). The experiments showed that the forcing of traps on a drain, during the passage of sewage along the drain, is not liable to occur, even where there is no ventilating opening at all on the drain, but that it is on account of the syphonage of traps, which may occur under certain circumstances, that suitable openings on a drain are required. They also indicated that if there is only one soil pipe, as in a cottage, such syphonage is prevented by one opening in the drain, and that this opening should be the usual ventilating opening at the top of the soil pipe; and that if there is more than one soil pipe, each should be ventilated in this way.

The Trap as a Passive Obstacle to Sewage.

13. We may now consider the objection that the intercepting trap is an obstacle to the flow of sewage. It is contended by opponents of the trap that it is always a passive obstacle and is never clean; that, on the contrary, under conditions of practical working, it usually contains sewage; and that, as this retained sewage is undergoing decomposition, the result is that the sewer receives, from the trap, sewage which either has begun to decompose, or which, under certain circumstances, is in an advanced stage of decomposition. It is also claimed that, as the primary object of house drainage and sewerage systems, on which so much money has been spent in recent years, is to effect the rapid and complete removal of fouled water and excretal solids from the neighbourhood of the dwelling, this primary object is defeated, more or less, if, at the outset almost of their journey, their removal is retarded in consequence of some inherent feature of the system. It was urged by some witnesses that this tendency of the intercepting trap to retain sewage has a very important bearing on the offensiveness of sewer air, some claiming, indeed, that it is the essential cause of such offensiveness. For instance, Mr. Robson, Engineer of Willesden urban district, has found, by practical experience, that nuisance from a sewer street ventilator may often be remedied by flushing out and thoroughly cleansing intercepting traps in the neighbourhood.

On the other hand, it was urged that the volume of sewage contained in an intercepting trap is so small that, even if its contents happen to be in an advanced stage of decomposition, the effect on the relatively large volume of sewage in the sewer must, at the most, be trifling. Against this it is argued that, although the effect of the contents of an individual intercepting trap may be small, the total effect of the contents of all or of a large number of traps discharging into a system of sewers may be very great.

The question arises, therefore, whether under ordinary conditions the intercepting trap is, in fact, apt, habitually, to retain sewage matters, or, whether the retention in it of sewage instead of relatively clean water is merely an accidental or occasional event.

Islington Experiments.

14. Experiments carried out for us at Islington throw light on this question. These experiments were conducted with two arrangements of full-size half-channel drains, erected by Mr. Patten Barber, the Borough Surveyor, to represent, one an average installation of 4-inch house drains laid to a fall of 1 in 40, and the other an average installation of 6-inch drains laid to a fall of 1 in 60. Each of these drainage systems was connected at one end with an intercepting trap of the type to be tested, and at the other end with two ordinary water closets fitted with flushing

cisterns, one representing a ground-floor closet and the other a first-floor closet. A large cistern with a $1\frac{1}{2}$-inch discharge pipe was also placed in position corresponding to that of a bath on the first floor of a house. It was, therefore, possible to ascertain the effect of successive discharges of water, from water closets and a bath, on the passage of artificial excreta and paper along the drains and through various patterns of intercepting traps.

15. The results of many of these experiments are set forth in detail in Appendix IV. They show that none of the intercepting traps in common use, which were employed, was cleared of solid matter delivered to it by ordinary flushing of the water closet. This result was evident whether the trap was a 4-inch trap, a 6-inch trap, or one expanding from 4 inches to 6 inches; whether either form of trap was connected with a 4-inch drain or a 6-inch drain; and also whether a two-gallon flush or a three-gallon flush was used.

Thus, with the two 4-inch traps which gave the best results, the proportion of solids, both artificial excreta and paper, retained by the trap after each flush, based on the average of ten successive flushes, amounted to 42 and 49 per cent., when the trap was connected with the 4-inch drain and when the capacity of the flushing cistern was two gallons. With other 4-inch intercepting traps similarly connected and flushed, the average proportion of solid matters retained ranged from 59 per cent. to 79 per cent.

With a three-gallon flush, one of the 4-inch intercepting traps giving the best results retained an average of 40 per cent. of the solid matters.

The results were also unsatisfactory with 6-inch intercepting traps, or with a 4-inch intercepting trap connected with the 6-inch drain. In the latter case the trap retained, on the average, 52 to 67 per cent. of solids with a two-gallon flush, while the 6-inch traps, similarly flushed, retained from 73 to 78 per cent. of solids. With a three-gallon flush, the 6-inch trap retained an average of 72 per cent. of solids.

The tables and diagrams in Appendix IV., show how uniform was the tendency of all the traps used to retain a large proportion of the solids at any given flush. A noticeable feature also of many of the experiments was that solids accumulated in the trap during two or three successive flushes until a certain amount of obstruction had been reached, and that then a flush effected a considerable clearance.

Other important results of the experiments showed that a long continued discharge of water, such as that obtained by emptying a fixed bath, is very effectual in clearing solids from an intercepting trap, but that the discharge of pails of water down a water closet is not more effectual, for this purpose, than the discharge from a two-gallon or a three-gallon flushing cistern. The experiments also showed that solids pass along a 4-inch drain with a gradient of 1 in 40 more satisfactorily than along a 6-inch drain with a gradient of 1 in 60.

16. Somewhat similar experiments were carried out in 1893 by a Committee of the Royal Sanitary Institute,* although they differed in an important respect from those at Islington. In the former, if any artificial excreta or paper were retained anywhere in the experimental installation of drains after a given flush, they were removed before the next flush, but in the Islington experiments such retained materials were not removed, as it was considered that, thereby, a nearer approach to actual practical conditions would be attained. Nevertheless, the experiments of the Sanitary Institute showed that an average of 37 per cent. of solids were retained in 4-inch traps, connected with 4-inch drains with 1 in 40 gradient, when flushed with a two-gallon cistern, and 25 per cent. when flushed with a three-gallon cistern.

17. Consequently, both series of experiments support the contention that the trap is an important impediment to the passage of solid matter in sewage from the house drain to the sewer, and that it tends to promote decomposition of sewage before it can reach the sewer. It is reasonable to expect, and the Islington experiments bear this out, that the liability of an intercepting trap to contain decomposing sewage, at any given time, is less in a house containing a bath in daily use, than in one without a bath. It is possible, however, that, in actual practice, a bath may not be so useful in this respect as the experiments seem to indicate, for in many dwellings the bath discharges

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* Journal of the Royal Sanitary Institute, Vol. XIV., p. 237—1893.

commonly take place before those from closets. It would appear, however, that, in the absence of a bath, the intercepting trap is unlikely to be free at any time from solid fæcal matter. It is a fair inference, therefore, that, when conditions favour active decomposition, the contents of numerous intercepting traps may become very offensive before they reach the sewer.

The arrangements used in the Islington experiments were devised with great care by Mr. Patten Barber so as to represent average artisan house drainage systems, but it was obviously impossible to reproduce all the actual conditions of every-day practical use. For instance, the effect of grease and other contents of domestic sewage could not readily be reproduced, nor could such conditions as inadequate or uneven gradient and other common drain defects be taken into account. It is probable, therefore, that, with a similar arrangement of drains, the tendency of an intercepting trap to retain solid matter may be even greater than the experiments indicated. A similar reservation was regarded as necessary by the Committee who reported on the experiments at the Sanitary Institute.

Blocking of the Intercepting Trap.

18. Perhaps the most important disadvantage alleged against the intercepting trap is that, besides its liability to be a passive impediment to the passage of sewage solids to the sewer, it may be the active cause of more or less complete obstruction of the house drain, with consequent accumulation of sewage in the drain.

Opponents of the trap contend that this blocking of the trap is a very serious matter; that the resulting accumulation of sewage may leak, through the joints of the drain and the brickwork of inspection chambers, into the basements and foundations of houses; and that to deal with this accumulation of sewage and to remove the obstruction is a difficult and offensive proceeding.

On the other hand, it is urged that the blocking of a trap is not a frequent occurrence; that, when it does occur, it is generally due to the carelessness or ignorance of householders in passing improper materials into the drain; that, as the existence of a block should soon become evident, there is not much opportunity for the leakage of sewage from the drain before the block is removed; and that, with a proper "raking arm," any accidental accumulation of sewage is easily got rid of.

Existence of Block not usually Discovered.

19. At the outset of our inquiry, however, it was shown that the existence of a block at the intercepting trap does not necessarily become evident in a short space of time; indeed, it was shown that it may not become evident at all. This is not so surprising as it seems, and the explanation is quite simple, but it is important that it should be thoroughly understood.

The existence of a block at the intercepting trap, as of a block anywhere else in a drain, is first shown, unless the trap is specially exposed to view, by the drain not acting properly, as indicated by sewage remaining ponded, more or less, at the surface of one or other of the visible traps on the drain, instead of passing away freely. As the intercepting trap is usually the lowest point of the house drain, it follows that, before the existence of a block in the trap can become apparent in this way, sewage must accumulate in the whole length of the drain between it and the level of the next lowest trap on the surface. That is to say, until sewage having so accumulated, appears and remains visible at the surface, it is not evident, from the ordinary use of the drain, that the drain is obstructed or that there is an accumulation of sewage in it.

In order, however, that an accumulation of sewage to this extent can take place, not only must the whole of the drain be watertight, but the block itself at the intercepting trap must also be watertight. If the block is not watertight, as is nearly always the case, the length of time, which is needed for the drain to fill to the level of the lowest surface gulley, will depend on the balance between the volume of liquid leaking through the blocked trap, under a steadily increasing head, and the volume of water entering the drain. Bearing in mind the usual intermittency of discharges into a drain, it is evident that the process of filling up the drain may be prolonged, even if the drain itself is quite watertight.

Again, in many modern house drainage systems, there are often inspection chambers, and these provide another condition which tends to prevent the rapid rise of sewage in a drain, blocked at the interceptor, to the level necessary to make it visible. One inspection chamber at least is usually provided to afford means of access to the intercepting trap (there are frequently others), and this chamber must be filled, as well as the drain itself, to the level of the next lowest surface trap before it becomes apparent that the drain is obstructed. As inspection chambers are even less likely to be watertight than the drain itself, their construction, as well as their capacity, helps to retard the rapid rise in the level of the blocked sewage. If, as is sometimes the case, the cover of the main inspection chamber is at a lower level than the lowest surface gulley, the first evidence that the drain is obstructed at the intercepting trap will be the overflow of sewage from the inspection chamber over the adjoining ground.

It is also established, as will appear presently, that not infrequently a block is formed at the intercepting trap, and that the pressure of the accumulated sewage, after rising in the drain and inspection chamber to a certain level, forces the obstruction before it becomes evident from the use of the drain that it had been obstructed. Therefore, a given intercepting trap may be repeatedly blocked, and the block repeatedly overcome by the pressure of accumulated sewage, and the existence of such a condition may remain altogether unsuspected.

20. Such then are the reasons why blocking of the intercepting trap may be unknown. It is obvious that, under any circumstances, the effects produced by such blocking are very undesirable; and it is disquieting that with ordinary use of the drain their existence is unlikely to be known for a more or less prolonged period, if at all. It is conceivable that the effects might be disastrous, if, for instance, a well supplying drinking water happened to be in the vicinity of such a blocked, and perhaps leaking drain; but, apart from this, the percolation of sewage into the soil near a dwelling may be fraught with serious consequences.

In Stockport, Sheffield, and elsewhere, we were informed that, frequently the first indication of a blocked intercepting trap has been the appearance of sewage in the cellar under the dwelling. In these towns, as in other towns in the north of England, houses are often built with a passage between a pair of houses giving access to the back yards, and in this passage a drain common to two or more houses usually exists, so that where houses are provided with cellars, also not infrequent in northern towns, the drain in this passage has a cellar on either side, and at a lower level. Sometimes such cellars are used for the storage of food. In Stockport, the use of the trap has been abandoned, partly in consequence of the trouble caused by the flooding of cellars in this way.

Frequency of Blocking of the Trap.

21. The evil effects likely to follow from the accumulation of sewage in, and its leakage from, house drains might be multiplied, but it is needless to pursue the matter, for the real question of importance is whether the opportunity for the production of these effects is one which frequently occurs, or, whether it is so rare that it may be regarded as relatively of but little consequence.

In Willesden, the Medical Officer of Health, Dr. Butler, has found, as the result of systematic examinations from time to time of intercepting traps, that from 2·6 to 9·7 per cent. of the traps were blocked. The total number of traps examined was 6,745, and the total number of inspections during the years 1905-10 was 32,229. The total number of blocks found was 1,189, or 3·7 per cent. of the total inspections. It must be borne in mind that in none of these 1,189 blocked intercepting traps was there any evidence that a block was in existence until the traps were exposed to view.

TABLE SHOWING RESULTS OF INSPECTION OF MANHOLES IN WILLESDEN, 1905—1910.

Date.	Total Inspections.	Drains choked at Interceptor.	Percentage.	Stoppers of raking arm missing.	Percentage.
(1)	(2)	(3)	(4)	(5)	(6)
October, 1905	6,745	288	4·3	654	9·7
January, 1906	504	49	9·7	41	8·1
November, 1906	5,322	204	3·8	266	5·0
Various dates, 1907	1,227	119	9·7	33	2·7
„ „ 1908	5,548	190	3·4	83	1·5
„ „ 1909	6,144	158	2·6	110	1·8
„ „ 1910	6,739	181	2·7	73	1·1
Total	32,229	1,189	3·7	1,260	3·9

22. We had an opportunity of seeing some of the traps thus ascertained to be blocked, and they were in a remarkable condition. They had evidently been blocked for a long time, the inspection chambers each containing an accumulation of sewage covered with a dense scum, similar to that which forms in the septic tanks of sewage disposal works, but nevertheless the house drains were acting as though a block did not exist. In one case, in which the scum on the sewage in the inspection chamber was especially dense and old, and the level of accumulated sewage was high, even the discharge from a fixed bath, filled with water to the brim, failed to reveal the fact that the drain was blocked. All the bath water passed freely through the gulley trap into which the bath waste discharged, as if the drain was free from any obstruction. In the inspection chamber the level of sewage rose slowly, and, when the discharge ceased, slowly fell again.

23. In view of the conditions found in Willesden we considered it desirable to ascertain whether similar conditions existed elsewhere, and for this purpose we communicated, as we have already stated, with the sanitary authorities of the suburban districts of London, these districts being chosen as being likely to contain a large proportion of modern systems of house drains, the intercepting traps of which could be easily inspected, and comprising both working class and residential populations. These authorities were each requested to carry out a systematic examination of a large number of traps in order to ascertain how many were blocked, and how many, though not blocked at the time of inspection, showed signs of having been previously blocked, as well as other particulars which will be referred to later. It was specially desired that the traps so examined should not include any which were subject to " back watering " from the sewers.

24. Eventually, in response to our request, 6,492 intercepting traps were examined in 21 sanitary districts, with results that are shown, in detail, in Appendix II., p. 50. Of the traps examined, 445, or 6·9 per cent., proved to be blocked at the time of examination. Particulars of previous blocking were given in regard to 5,601 traps, and of these 932, or 16·6 per cent., gave evidence that, at one time and another, they had been blocked sufficiently to cause an accumulation of sewage in the inspection chamber.*

Traps blocked at the time of examination, and those indicating occurrence of previous blocks, added together, comprised over 23 per cent. of the total traps examined for both conditions.†

25. The results obtained from these widespread examinations confirm in a striking manner the results obtained in Willesden, and indicate that the latter were not exceptional. It cannot be said in face of them that the blocking of the intercepting trap is so infrequent as to be unimportant. On the contrary, many will be of opinion that the facts, indicating, as they do, that, in modern intercepting traps, over 23 per cent., or nearly one in every four, are likely to have been blocked at one time or another, unknown to their users, show, at least, the necessity of finding an effectual remedy if the trap is essential, or of considering its abandonment if it is not essential.

Causes of Blocking.

26. An important question, in relation to remedy, is whether any definite cause or causes, extraneous to the trap, can be assigned for the conditions found. It is well known that substances may find their way into house drains which ought not properly to be there, and instances were given by more than one witness of remarkable things which have been found in drains. Several witnesses expressed the opinion that the usual cause of a blocked intercepting trap is the presence of some such improper substances as a brush, article of clothing, and so forth, but other witnesses stated that examination of blocked traps does not show this to be the case.

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* The percentage of blocked traps in the various districts ranged from 1·5 per cent. to 25·3 per cent. but in four districts only did it exceed 10 per cent., while the percentage of traps giving evidence of previous blocks ranged from 0·5 per cent. to 53·6 per cent. In none of the series of traps examined was there a complete absence either of blocks at the time of inspection or of evidence of previous blocks.

† In two of the districts they comprised less than 6 per cent. of the total examined, in ten districts the proportion ranged from 12 to 25 per cent., and in the remaining five districts it ranged from 25 to nearly 57 per cent.

Possibly there is a tendency to assume, when a block is found, that some foreign substance must have been responsible, and in many cases this may be a correct assumption. But it is not easy to be certain on this point, for it is extremely difficult to ascertain with precision what has been the origin of a given block at an intercepting trap.

If the steps usually taken to remove the obstruction are successful, the primary obstructing substance, if any, is thereby removed into the sewer, and is not seen. Indeed, unless special examination is made, involving the careful baling out of accumulated sewage so as not to disturb the block, and thereafter the careful examination of the obstructing mass in the trap—both extremely disagreeable operations—it cannot be said what has been the cause. In two cases this special examination was made at our request, one being that already referred to in Willesden, the other a case seen by us in Gloucester. In neither case was any foreign substance found in the trap, but merely a mass of *débris* of paper and sludge. It is probable that blocking of the trap originates in most cases from the tendency of the trap to retain solid sewage matters, which was demonstrated by the Islington experiments.

27. It is noteworthy that the evolution of the intercepting trap, from its earliest form to that of the present day, has been marked by the introduction of modifications and of appliances, the express object of which has been, not only to render blocking less likely to occur, but also to facilitate the removal of any obstruction and the resultant accumulation of sewage. Following the square-shaped dip or "Mason's" trap came the "running" trap, merely a curved stoneware pipe, without any means of access, so that the removal of a block in the trap involved excavation of the ground and opening of the drain. To overcome this objection, a perpendicular pipe was often inserted into the dip of the trap and brought up to the ground level, so that in the event of obstruction a plunger could be used without disturbing the ground, but the position of this pipe was such that it became easily fouled at its junction with the trap and thus was apt to be the focus for the gradual formation of a block. In the next improvement this perpendicular pipe was placed, not at the dip, but at the entrance to the trap, and in this position, besides overcoming the last objection, it also served as an inlet for fresh air to the drain, while in the event of obstruction a plunger could still be used with effect. This air-inlet at the ground level, however, frequently became choked, or proved to be a nuisance through acting as an outlet for air as well as an inlet, and it was, therefore, elevated a few feet from the ground and provided with a grating and a light flap, as already described. The elevation of the air-inlet, however, prevented its use as a means of access for a plunger in the event of a block, and other means of access had to be provided. Usually this takes the form of an inspection chamber in the wall of which the trap is placed. Above the trap, a pipe called the "raking arm" is also usually provided, connecting the inspection chamber with the sewer connection* beyond the trap, for the purpose of emptying the chamber should an accumulation of sewage take place and for clearing the sewer connection. The opening of this pipe into the chamber is closed with a stopper in order to prevent access of sewer air to the drain.

Displacement of Stoppers in Inspection Chambers.

28. The stopper of the raking arm has raised another difficulty. In order to be of real use, in the event of an accumulation of sewage, it should be so loosely in its place that it can be easily withdrawn, even when considerably below the level of sewage in the inspection chamber, but if thus loosely fixed it is apt to be accidentally displaced. When this occurs, not only may the stopper fall upon the mouth of the trap and become a cause of obstruction, but, the raking arm being open, sewer air is admitted into the house drain, and thus the main object of the trap is defeated.

This displacement of the stopper of the raking arm appears to be not an infrequent occurrence. In Bournemouth, on examination of 400 house drains, as many as 25 per cent. of the stoppers were found to be missing. In the examination of intercepting traps in suburban districts, already referred to, the stopper of the raking arm was found displaced in 6 per cent. of the traps, and in Willesden the proportion was about the same, taking the examinations in the aggregate. In Willesden, however, the proportion was much higher in the first examinations, namely, nearly 10 per cent., and in the subsequent examinations the proportion declined until, at the last examination, it amounted to only 1·1 per cent. (See table on p. 7.) The explanation of this decrease is that, after the first examination, steps were taken to prevent the accidental displacement of the stopper, either by fixing it firmly in position, in which case it consisted of a piece of glass, slate, or other substance easily broken when necessary and easily renewed, or by using a mechanical device which, while holding the stopper firmly in position, enables it to be removed, if necessary, by pulling a chain. The former method is cheap and effectual, but it is open to the objection that the stopper requires to be renewed after it has been broken in order to remove accumulated sewage, while the latter method is more expensive and is also open to the objection, common to many mechanical contrivances exposed to moisture and seldom used, that it may fail to act when needed.

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* By the term "sewer connection," here and elsewhere in the report, is meant the pipe between the house drain (which is regarded as terminating at the curtilage of the house) and the sewer. In some localities, the term used for this pipe is "drain connection."

Some witnesses expressed the opinion that, if displacement of the stopper of the raking arm could be effectively prevented, the liability of the intercepting trap to be blocked would be practically abolished. The only direct evidence bearing on this point was that submitted by Dr. Butler in his table (p. 7), which indicates that, although the proportion of displaced stoppers may be greatly reduced by the measures referred to, nevertheless the proportion of blocked traps is not diminished to an equal extent.

Flushing Cisterns.

29. The capacity of the water closet flushing cistern is regarded by many as of great importance in relation to the blocking of intercepting traps and their tendency to retain sewage, and several witnesses expressed the opinion that the usual two-gallon flush is insufficient and ought to be increased. Many water authorities, however, not only object to, but prohibit, a greater flush than two gallons, while there are few, we believe, who assent to a larger flush than three gallons, and it is unlikely, with the growing demands of an increasing population on available water supplies, that water authorities will be easily prevailed upon to relax such restrictions.

In the Islington experiments there was little or no difference, in their effect on the solid contents of an intercepting trap, between a two-gallon and a three-gallon flush, and even a four-gallon flush did not always completely clear the intercepting trap of solids (Appendix IV., Tables 3 and 4, 6 to 8, and 15 to 18).

Cascade.

30. Again, intercepting traps have been made with what is called "cascade," that is, with more or less appreciable drop between the invert of the drain where it joins the trap and the normal level of the water in the trap, with a view to lessen the liability of the trap to retain sewage and to become blocked.

In one trap described to us, that used at Shoreditch, this cascade extends sometimes to several feet, but usually it does not exceed three inches. The Islington experiments indicated, however, that the presence or absence of cascade did not have much effect on the results. Indeed, one of the traps which gave the best results was without cascade.

One witness expressed the opinion that the gradient of the drain should be increased in the length of pipe nearest the trap, with a view to increasing the velocity of the sewage immediately prior to its entrance into the trap, but the Islington experiments again did not indicate that this device is of service.

Capacity of the Trap.

31. It has also been sought to remedy the tendency of the intercepting trap to retain sewage and to become blocked by contracting its capacity. The Islington experiments showed that traps with small capacity gave the best results—viz., 4-inch traps of compact shape—but it has already been shown that the results so obtained were by no means satisfactory.

It seems to be probable, however, that if the diameter of the trap could be materially reduced the tendency to retain solid matters would be largely diminished. An experimental trap 3 inches in diameter, devised by Mr. Patten Barber, gave results far superior to those obtained with traps in common use, or with similar experimental 3½-inch or 4-inch traps (Appendix IV., Tables 20, 21 and 22). Theoretically, it seems clear that the diameter of the trap ought to be less than that of the drain to which it is attached. When water is discharged into a drain from a water closet, bath, sink waste, or yard gulley trap, it does not fill the drain, if it is free from obstruction, but, spreading itself longitudinally, seldom occupies more than about one quarter or one third of the vertical diameter of even a 4-inch pipe. Consequently, when the water in such a drain reaches a 4-inch intercepting trap, the effect is much the same as if, say, a 2-inch pipe running full were discharged into a 4-inch pipe.

If domestic sewage consisted entirely of liquid, no difficulty would be involved by considerably reducing the diameter of the trap, but the presence, not only of the ordinary solids in sewage, but also the occasional presence of extraneous matters, makes it doubtful whether this is practicable. The problem in this connection seems, in fact, to be on the horns of a dilemma. Either the intercepting trap must be large, so that it may not be easily blocked by extraneous matters, in which case it is liable to retain 40 to 79 per cent. of ordinary solids passing through it on any given occasion, thus tending not only to produce offensive sewage in the sewer, but also to encourage the formation of an actual block ; or the trap must be small, in which event it may be doubtful whether some solids, which may reach the trap, can pass through it at all. Obviously there is a limit to the reduction of the diameter of the intercepting trap.

32. Nevertheless, there appears to be much in favour of a 3-inch trap as compared with a 4-inch trap. Direct experiment showed that a trap of this size is not too small for ordinary sewage solids, or even for such an article as a duster, while, as we have already said, the results with successive water closet discharges were far superior to those obtained with any other trap, but we think that further experiments with a trap of this size, under actual working conditions, would be desirable.

Necessity of Providing against Effects of Block.

33. It is inevitable, however, that the use of any intercepting trap involves the necessity of making adequate provision for dealing with the results of a block. The provision usually made at the present time is, in our opinion, very unsatisfactory. As we have shown, the raking arm is often useless owing to the impracticability of removing the stopper when it is submerged in sewage ; and in these circumstances the only remedy possible is to bale out and to dispose of the sewage, somehow, from the inspection chamber, until the stopper can be reached. Moreover, the existence of a stopper easily broken, or of a satisfactory locking stopper, does not provide against the other objectionable results of an undiscovered block to which we have referred.

It has been urged that periodical examination of the inspection chamber supplies an easy method of ascertaining the existence of a block, which is not apparent from ordinary use of the drain, and that the householder should be expected to make such examination. But a householder very rarely examines his inspection chamber, if there is one, and compulsion in such a matter is impracticable. If periodical inspection were the only remedy, it would be necessary to make it a duty of the local authority, but even if such an expensive method as this were practicable, the question would arise how frequent the inspection would need to be. The figures submitted by Dr. Butler indicate that, to be of real value, it would require to be very frequent indeed.

We are of opinion, however, that a system of drainage which calls for such repeated inspection is objectionable, and that the only satisfactory system is one which, while usually working well, will show quickly, in the course of ordinary use, if it is out of order, and which, when out of order, will admit of easy remedy without nuisance. What is wanted, in short, is a system which will ensure, firstly, that the drain will rapidly fill, if the block at the intercepting trap is dense, to the level of the lowest trap in common use ; and, secondly, that there will be no leakage from the drain if delay must occur before its existense is discovered, owing to the block not being watertight.

Closed Drains in Inspection Chamber.

34. The first of these requirements involves the abolition of the usual open channel drain on the floor of the inspection chamber, and the provision of a closed drain to the intercepting trap, in order to prevent the access of sewage into the

inspection chamber. This means that the length of drain on the floor of the chamber must be provided with a removable cover, so that it may be opened, in the event of a block, in order to allow sewage, accumulated in the drain, to escape through the "raking arm," the stopper of this having previously been removed. Such an arrangement as this is already on the market, constructed either of iron, somewhat similar to a hatch box on a water main, or of stoneware, and we understand that its use involves no difficulty or prohibitive expense. This requirement also applies, of course, to any inspection chamber there may be between the intercepting trap chamber and the lowest surface gulley.

Iron Drains.

35. The second of the requirements raises the question of the watertightness of the ordinary stoneware drain, and the desirability of using drains made of iron. A number of witnesses urged that stoneware drains are unreliable and seldom remain watertight even when they are constructed with great care, and instances were given of such drains being found to be leaky very soon after construction. It was also urged that iron drains are much less likely to become leaky in adverse conditions; that they are easier to construct; and that their extra cost is not so serious as is commonly supposed.

36. Dr. Meredith Richards, Medical Officer of Health of Croydon, has informed us that in that town the cost of iron drains is about 20 per cent. higher than the cost of stoneware drains, and he states that, in a typical terrace of cottages, in his district, this means an extra outlay of about £4 per house. Mr. Gilbert Thomson has submitted details of two actual tenders received by him for the construction of the drains of a hospital in Scotland, in iron and stoneware, respectively, from which it appears that, although the cost of iron pipes is approximately double that of stoneware pipes, the cost of laying iron drains is much less than double that of laying stoneware drains, owing principally to the necessity of providing a concrete bed for the latter. If comparison be restricted to the underground drains alone, the extra cost of iron drains was in one tender 16 per cent., and in the other 22 per cent., but if comparison be made of the total cost of the complete drainage installation, that is, inclusive of soil pipes, waste pipes, sanitary fittings, etc., the extra cost, in consequence of the provision of iron drains, amounted only to 9 per cent. and 12 per cent. in the two tenders respectively.

Mr. Gilbert Thomson also informed us that drains constructed of iron may be made, not only watertight, but airtight also, so that their soundness will admit of simple test by air pressure both on completion and periodically afterwards. Mr. Robertson Best gave instances of iron drains which after a lapse of 30 years were found to be "as good to-day as the day they were put in."

37. There is evidently much to be said in favour of iron drains, and were it not for their greater cost, we presume that they would be more commonly used than they are. In the case of that portion of the drain which must inevitably be filled with sewage, when the intercepting trap is blocked, it is a serious question whether stoneware should be allowed at all. There seems to be no doubt that an iron drain is a great safeguard against leakage of sewage, and bearing in mind that such leakage, apart from its immediate effects, may also result in complete ignorance of the existence of a block at the intercepting trap, it is clearly desirable that the drain leading to this trap should be of iron. If such a drain is near a house, or near the cellar of a house, or in the vicinity of a well supplying drinking water, we consider that an iron drain is essential, when an intercepting trap is used.

38. If, therefore, the access of sewage to the inspection chamber is prevented by closing the usual open channel drain, and the watertightness ensured, by use of iron pipes, of at least that portion of the drain between the intercepting trap and the lowest surface trap, the chances that a block at the intercepting trap will be quickly recognised must be greatly increased. If, on the other hand, delay occurs because the block is not watertight, the risk of the objectionable occurrences which we have described will be greatly diminished. At the same time, the removal of a block will not involve the difficulties at present experienced, for, having first withdrawn the stopper of the raking arm, opening the drain on the floor of the inspection chamber

will release the accumulated sewage and allow access to the block in the trap. Moreover, the stopper of the raking arm can be firmly secured against displacement, since it would always be accessible.

It thus becomes evident that one of the most serious disadvantages of the intercepting trap, namely, the unsuspected existence of a block and its effects, may be successfully overcome or provided for satisfactorily, but only by making the construction of house drainage more complicated and more expensive than it is at present.

Simplification of Drainage in Absence of Trap.

39. On the other hand, it is urged that if the intercepting trap may be omitted with safety there could be material simplification of house drainage. The proper setting of an intercepting trap appears in itself to be by no means a simple proceeding. For instance, it may be so fixed that it is tilted in one direction or another, in which event the water seal is either so great that the chances of obstruction are much increased or so small as to be almost non-existent.

Moreover, when the available fall between house and sewer is limited, the introduction of the intercepting trap may prove a serious difficulty and render necessary still further limitation of the gradient of the house drain.

40. It has also been maintained that the inspection chamber, which is commonly provided at the site of the trap, as a means of access to it, is unnecessary, in the absence of the trap, since in the event of obstruction in this portion of the house drain there should be no difficulty in effecting its removal by means of rods passed in from the higher portion of the drain. It is contended, however, that omission of the intercepting trap does not obviate the need for this inspection chamber, for the reason that, in its absence, the drain cannot be tested, without excavating the ground and breaking open the drain. One witness suggested, as a way out of this difficulty, that a plug might be passed down from the upper part of the drain and then inflated, but other witnesses pointed out that it would be uncertain whether such a plug was watertight, and the test would therefore be untrustworthy. Another method, which suggests itself to us, is to provide a removable cover on the pipe forming the lowest portion of the house drain, at its junction with the sewer connection, so that, if need arose to test the drain, this cover could be removed after excavation of the ground and a testing plug inserted there. But, although an inspection chamber does not appear to be so important at this spot when the intercepting trap is absent, we are of opinion that it would generally be desirable to provide it.

PART II.

ADVANTAGES OF THE INTERCEPTING TRAP.

The Trap as a Barrier to Rats.

41. An incidental advantage claimed for the intercepting trap is that it prevents the passage of rats from the sewer into the house drain. Apart from the undesirability on general grounds of the presence of rats in and about houses, such an advantage might be of very great importance in connection with plague. It appears to be doubtful, however, whether the intercepting trap is a barrier to the rat, for rats have been observed to pass through it, both from the drain into the sewer, and from the sewer into the drain. Mr. Patten Barber informed us that he had seen rats chased into the inspection chamber of a drain, where it was supposed that the intercepting trap would have checked their further progress, but it was found that they had escaped through the trap into the sewer. Conversely, Mr. Woods, the chief sanitary inspector of Willesden, informed us that, during the reconstruction of the inspection chamber of a house drain, he saw three or four rats, in succession, come through the water in the intercepting trap from the sewer and disappear into the house drain.

The Trap as a Barrier to Sewer Air.

42. The fundamental advantage claimed for the intercepting trap is that it prevents the passage of air from the sewer into the house drain, and thus that it prevents the entry of sewer air into the dwelling. In this connection, two questions of importance arise ; one, whether it is necessary to exclude the air of the sewer from the house drain ; the other, whether, as a matter of fact, the intercepting trap does prevent the access of sewer air into the house drain.

43. Many observers are of opinion that the trap is of little avail in excluding sewer air, and in Germany this appears to be the accepted official view. Professor Dr. Schmidtman, of the Supreme Medical Council, Berlin, has informed us that "intercepting traps at the junction of house drains with street sewers are almost "nowhere in use in Germany, and are in many places directly forbidden, *e.g.*, in the "kingdom of Saxony and in Cologne. In Germany we are of opinion that such "traps are in no way capable of preventing the sewer gas from getting into the "house. As soon as there is pressure in the sewers (*e.g.*, owing to heavy rains) the "gas passes through the intercepting trap into the house drain. In Germany, there"fore, the ventilation (intercepting traps being omitted) is effected by ventilating "shafts carried up above the roofs of the houses. Inside the house the escape of "smells at each entrance to the drain is prevented by water sealed traps."

44. The water seal of the intercepting trap, which forms the barrier to the passage of sewer air, varies in depth from 1 to 3 inches. Theoretically, such a seal is unable to withstand a pressure of more than 2 oz. per square inch ; that is to say, when, from any cause, pressure in the sewer exceeds the resistance afforded by the seal, air should pass from the sewer into the house drain, in spite of the existence of the trap.

45. In practice, however, conditions appear to be very different from those just stated. Usually sewers have many designed outlets for air, but, even if these are absent, the sewers are not airtight, which is not surprising, having regard not only to the joints of the pipes or brickwork of the sewers themselves, but also to the manhole and inspection chambers and their covers, as well as numerous sewer connections. Indeed, as we have already mentioned, it is difficult to construct even house drains in stoneware that are airtight. Conditions therefore which, theoretically, ought to compress air in sewers do not do so, or at all events do not, as will be seen, necessarily involve pressure on, or the passage of air through, the intercepting trap.

Bristol Experiments.

46. Some striking experiments, details of which are given in Appendix III., (Experiment G., pp. 51 and 52), were carried out by Mr. Steele and witnessed

by us at Bristol, where, as is well known, designed sewer ventilation is totally absent. An intercepting trap, provided with observation windows, was attached to a sewer connection on one of the main tide-locked sewer outfalls to the river, and it was found that although, during the rise of the tide, sewage accumulated steadily in the sewer, with consequent tendency to compression of air in it, there was at first an absence of pressure on the water in the intercepting trap. In fact, there was no sign of pressure on the trap until the sewage had risen to such a height in the sewer as to submerge the outlet of the sewer connection; that is to say, until after the aërial continuity of sewer and sewer connection had been interrupted. Thereafter, with tide still rising and sewage now rising also in the sewer connection, pressure on the seal of the trap became evident, and air from the sewer connection bubbled through the water in the trap into the house drain. The bubbling of air through the water of the intercepting trap continued so long as the sewage continued to rise, but afterwards, when, owing to ebb of the tide, the level of the sewage fell, air passed in the reverse direction, from the house drain into the sewer connection. This continued until the level of sewage had fallen to that necessary to restore the aërial continuity of sewer connection and sewer, and when this stage was reached the balance of air pressure on the seal of the intercepting trap was restored, suddenly, to normal, showing that while the lowering of the sewage had rarefied the air in the sewer connection it had not done so in the sewer itself.

As a matter of fact, during these experiments, the intercepting trap was not forced until the level of the sewage in the sewer was no less than 3 ft. higher than the opening of the sewer connection into the sewer. That this amount of head was required to force air through the trap showed that even the sewer connection was not airtight, although it had been constructed with special care. In a subsequent experiment, on a drain experimentally constructed and proved to be airtight, it was found that air was forced through the trap when the pressure in the sewer connection just exceeded the resistance of the trap.

47. These experiments are of fundamental importance. It is obvious that if, in an unventilated system of sewers, an intercepting trap is not affected by considerable rise of sewage in a sewer, until the opening of the sewer connection, to which it is attached, is submerged, it is still less likely that such a trap will be affected in a ventilated system of sewers under similar circumstances. It is also obvious that the effect produced at Bristol on the trap after the sewer was "cut off," as it were, by submersion of the sewer connection, was one which is not and cannot be influenced by ordinary sewer ventilation. The conditions necessary to produce this effect are precisely the same whether the sewers are or are not ventilated, unless every sewer connection is provided with a separate ventilating shaft.

The explanation of the absence of pressure on the intercepting trap, so long as there remained aërial continuity between sewer connection and sewer, must be that the air in the sewer itself found its way, despite absence of ventilation, through unknown outlets, and through the walls of the sewer into the soil and elsewhere, since, like any other network of stoneware or brick sewers, the Bristol system cannot be airtight. Nevertheless it is a striking fact that in Bristol, where, owing to the remarkable combination of absence of intentional sewer ventilation and the exceptionally large tidal rise of the river, some pressure on the intercepting trap from rising pressure in the sewer might have been expected, no such effect was, in fact, produced, so long as the air of the sewer itself had access to the seal of the intercepting trap.

48. Another important result shown by these experiments was that when a trap is forced by air pressure, the water seal, though reduced in depth, is not liable to be destroyed.

A trap may be regarded as a U tube, in which water will be depressed in one limb by pressure of air and elevated in the other, until the level of the depression reaches the curve of the tube, when air will pass through the water. At this stage the tube (trap) is "forced," but even assuming that the whole of the water which has been elevated in one limb of the tube has overflowed and has been lost, which is not usually the case, there will remain in the tube a volume of water equal at least to one limb of the tube *plus* that filling the curve of the tube, or more than is necessary to seal the tube (trap), when pressure becomes normal and the water in each limb becomes level.

Sudden Increase of Pressure in Sewer.

49. When air pressure in the sewer is increased with great rapidity and suddenness, as, for instance, in severe rain storms, it might be supposed that pressure on the seals of intercepting traps, to the extent of forcing air through them, may be more likely to occur than when the air in the sewer is compressed gradually. We have had no direct evidence, however, that this is the case, and it is not clear that it does happen so long as the opening of the sewer connection into the sewer is not submerged.

The fact that many intercepting traps show, on examination, that the stopper of the "raking arm" has been forced out of position indicates that there must have been pressure also on the seal of the intercepting trap, but it is uncertain whether this happens unless the aërial continuity between the sewer connection and sewer is first interrupted.

It has also been observed that, during the flushing of small sewers air is forced through the intercepting trap. It is probable, however, that, in the process of flushing, the outlet of the sewer connection is temporarily submerged, and that consequently the forcing of the trap under these circumstances may be merely another example of pressure arising in the sewer connection only.

Again, in times of excessive rain it occasionally happens that the cover of a sewer manhole is lifted, sometimes with explosive force, and this has been referred to as an example of excessive pressure in the sewer, which must have involved the forcing of sewer air through intercepting traps in the neighbourhood. The pressure required to lift a manhole cover in this way does not appear to be so great as might be imagined. It has been calculated that the pressure required may be less than 1 lb. per square inch, or, say, a head of 2 ft. of water above the top of the sewer. Moreover, such lifting of a manhole cover occurs only when air is imprisoned in the manhole chamber itself, owing to the rise of sewage above the top of the sewer; that is to say, when sewage has risen to such a level that the outlets of sewer connections must previously have been submerged. In these circumstances, the intercepting trap can be forced only by pressure of air from the sewer connection, as in the Bristol experiments.

Another form of pressure in sewers which is alleged to result in the forcing of intercepting traps is that brought about by the emission of gaseous products from stagnant and decomposing sewage. There has been no direct evidence on this point, but witnesses with knowledge of chemistry expressed to us great doubts as to the possibility of such an occurrence. The emission of such gases is a gradual process and the effect is broadly the same as that produced when gradually increasing pressure occurs in sewers as in the Bristol experiments.

50. On the whole, therefore, it would appear, according to the evidence presented to us and according to our own experimental observations, that, under practical conditions, the intercepting trap usually answers its purpose as a barrier to the passage of air from the sewer into the house drain.

Main Channels of Escape of Sewer Air into a House Drain.

51. We may now consider the question whether it is necessary to exclude sewer air from the house drain. The object of excluding it is, of course, to ensure its exclusion from the interior of the dwelling. In the absence of an intercepting trap, the main channels by which it is supposed that sewer air may find its way into the house, are through some defect or defects in the underground drain or in the pipes above ground, or by being wafted from the top of the ventilation shaft of the drainage system through open windows or down chimney shafts into dwelling rooms. Not only may sewer air and drain air thus escape passively, as it were, from these sources, into the interior of the house, but also they may be actively drawn or aspirated into rooms in consequence of difference of temperature. The burning of a fire in a room, for instance, has been known to result in air being drawn from a drain into a room.

52. In considering this question it is necessary to recognise clearly the points at issue. For instance, the question is not whether, in the one case, when the intercepting trap is absent, sewer air may pass into the house, while in the other case,

when the trap is present, the house is free from all possibility of the entrance of air from either drain or sewer. If the drain is free from defects that allow escape of air from it, and at the same time if the ventilating shaft is in such a position that air escaping from it will not enter a room, it follows that, even if there is no intercepting trap, there is no possibility of sewer air escaping into the dwelling in either of these ways.

On the other hand, if it is possible, in the absence of an intercepting trap, for sewer air to pass or to be drawn *viâ* a given drain into a dwelling, it is equally possible, assuming now that there is an intercepting trap, for drain air to pass or to be drawn into the dwelling from such drain. Similarly, if in the absence of an intercepting trap sewer air *viâ* the ventilating shaft of a drain is likely in a given case to pass or to be drawn into a dwelling room, the likelihood of drain air so passing, if there is an intercepting trap, is precisely the same.

The problem really resolves itself, therefore, into the question whether there is any essential difference between the escape of sewer air *plus* drain air and drain air only; that is, whether the two together are more objectionable or more likely to cause ill-health than drain air alone.

Supposed Other Channels for Passage of Sewer Air.

53. It is said, however, that, if the intercepting trap is absent, sewer air may pass into the house by channels other than those referred to, for instance, through internal traps in the house itself, such as those of water closets and other sanitary fittings, as the result of being forced through their water seals in consequence of pressure in the sewer.

54. We have already shown that, even in unventilated sewers, the intercepting trap is not forced, under practical conditions, by pressure of air derived from the sewer itself, and it follows that, if the intercepting trap is absent, neither will the traps on the house drain be forced by such pressure. Moreover, when the intercepting trap is absent, the pressure, which may arise in the sewer connection after submersion of its opening into the sewer, and which, as we have shown, may force the intercepting trap, will not affect traps* on the house drain, for, in these circumstances, the ventilation shaft, which it is customary to provide on a house drainage system, acts as an alternative and easier outlet for air.

55. On the other hand, it is urged that the safeguard, in this respect, of the ventilating shaft may be destroyed, for instance, by the unknown existence of a block from an accumulation of rust, either at its foot, or near its top, if there is a pronounced bend or angle in the shaft. When the ventilating shaft is the soil pipe, as is usually the case, blocking at the foot is prevented by the action of water flowing down the soil pipe, but there seems to be no doubt that in the case of supplementary and independent ventilating shafts, made of iron, blocking in this way may occur very rapidly. It seems to be questionable, in view of the experiments detailed in Appendix III. (Experiments K., pp. 54-58), whether supplementary shafts are necessary in ordinary cases, although they may be desirable, perhaps, in complicated drainage systems, such as those of institutions and large buildings. It is not uncommon, by way of remedy, to provide a "rust box" at the foot of a shaft of this kind, into which rust may fall, clear of the air-way, and from which it may be periodically removed; moreover, it should not be difficult, in such cases, so to contrive the position of a supplementary shaft, that its junction with the drain shall be washed and kept clear by water flowing along the drain. But the blocking by rust, which sometimes occurs at a bend in a shaft, may affect a soil pipe, if the bend is above the highest water closet connection, although it is unlikely to occur unless the bend is abrupt. Moreover, if an abrupt bend (say, with an angle of less than about 135 degrees) cannot be avoided, blocking by rust can be prevented by constructing the top of the shaft or soil pipe of lead, from the bend upwards.

56. Assuming, however, that the ventilating shaft on a house drain is completely blocked as an outlet for air; and assuming, also, that air in the drain is compressed, after submersion of the outlet of the sewer connection,

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[*] It is assumed in this report that, in the construction of new house drainage, improper traps, such as that known as the "bell-trap," will not be used.

and that the only available channels of escape for the air are the traps on the drain it would appear that, nevertheless, this air will not necessarily escape, through the traps of sanitary fittings inside the house, into the interior of the dwelling. This was demonstrated by an important experiment, carried out by Mr. Steele at Bristol, and described in Appendix III., (Experiment E., p. 53.) Three traps, each with a different depth of water seal, were connected with a drain, specially constructed and proved to be perfectly airtight, and the air in the drain was then compressed against the traps by varying heads of water, in imitation of the effect produced by sewage rising in the sewer connection of a house drain. It was found that, when the head of water exceeded the resistance of the trap having the smallest water seal, air passed through that trap, but that, on increasing the pressure against the traps, air continued to escape through that trap alone, and never escaped through the other traps which had deeper water seals. Consequently, an internal trap in a house drain is not liable to be forced, unless its water seal is less than that of a trap outside the house.

57. Examples were given in evidence of the oscillation of water in, and even of the forcing of internal traps, in drains provided with the intercepting trap, as the result of wind pressure down the ventilating shaft of the drain. The latter occurrence, which involves, of course, the passage of drain air through the trap, cannot presumably take place unless the seal of the internal trap is weaker than that of the intercepting trap or of other traps on the drain. With no intercepting trap and a free opening from the drain into the sewer it is difficult to see how this action could exert pressure on the internal house traps.

58. Another possibility, which has been suggested, is that sewer air may be absorbed by the water in an internal trap and given off on the house side of the water seal. That soluble gases can be taken into solution on one side of a column of water and given off on the other is well known, and there is no reason to doubt that, in an unventilated drain, some of the gaseous contents of the drain in contact with an internal trap might be absorbed by the water in the trap. But this would happen whether the gaseous contents were solely drain air (if there were an intercepting trap) or, whether they were partly sewer air (if there were not an intercepting trap), so that here again the question is one between the importance of sewer air *plus* drain air as against drain air alone.

These supposed channels for sewer air to which we have just referred do not affect, therefore, the main question at issue. As already stated this question, for practical purposes, is whether, in a given dwelling, into which drain air can escape there would be any extra disadvantage if sewer air could gain entrance together with the drain air.

Iron Drains for Preventing Escape of Drain Air.

59. A solution of this problem which naturally suggests itself is to render impossible the escape of drain air as well as sewer air into a house, either from the drain or from the ventilating shaft.

So far as escape of air from the drain itself is concerned, one of our witnesses, Mr. Gilbert Thomson, claimed that this solution is practicable if the house drain is constructed of iron pipes with lead joints. Indeed, so convinced is he of the impossibility of laying stoneware drains so as to remain airtight, that for some years past he has declined, in his business, to construct any but iron drains.

Other witnesses with experience of drain construction stated that it is difficult to construct drains of stoneware so as to be watertight, and that even the best constructed stoneware drains may, in a short space of time, cease to be watertight and, therefore, airtight. Mr. Thomson stated that in only one case had he known a stoneware drain to be airtight some time after its construction.

60. If iron drains were compulsory and the workmanship good, the escape of drain air, or in the absence of intercepting trap, the escape of drain air *plus* sewer air from the drain itself, would be prevented, and the source whence drain or sewer air could then gain access to houses would be practically limited to the outlets of those ventilating shafts of drains from which such access was possible in consequence of their position.

Differences between Sewer Air and Drain Air.

61. The two opposing contentions in regard to the differences between drain air and sewer air are, broadly, as follows. On the one hand, it is said that as sewage comprises the contributions of drains the air contained in sewers cannot differ essentially from the air contained in drains. On the other hand, it is contended that sewer air usually differs from drain air, first, because sewage, composed though it is of the contents of drains, is more subject, under practical conditions, to changes produced by decomposition, and, therefore, contains dangerous gases; and second, because the air of sewers may contain microbes, given off from the sewage, which are capable of causing disease, and although, again, sewage microbes in sewer air, if they exist, are derived from the contents of the drains, they may include microbes which are not present in the sewage of all drains alike. Therefore, it is contended, sewer air may be a means of disseminating disease by carrying pathogenic microbes, derived from the sewage of one house, to the drain of another house, and thence into the house itself.

PART III.

CHEMISTRY OF SEWER AIR.

62. We had the advantage of hearing evidence on the chemistry of sewer air from Dr. J. S. Haldane, F.R.S., whose observations with the late Professor Carnelley on the air of the sewers underneath the Houses of Parliament, as well as of sewers in Dundee* and Bristol,† are well known; and from Dr. Hurtley, Lecturer on Chemistry at St. Bartholomew's Hospital, who has been engaged more recently in the examination of air in certain sewers in Hampstead,‡ from which offensive emanations had been complained of. We have also had before us the exhaustive report, recently published by Professor Delépine,§ of his prolonged chemical, bacteriological, and other investigations of the air of sewers in Manchester.

The results obtained by these observers are practically identical, and they indicate that in sewers, whether old or new, ventilated or unventilated, in which sewage is moving and is not lying stagnant, the air differs but little from that of the atmosphere outside. The only difference ascertainable by chemical analysis, apart from humidity, is that in sewer air there is somewhat more carbon dioxide, ammonia, and organic matter than in fresh air. The largest amount of carbon dioxide found by Dr. Hurtley in sewer air was 17 parts per 10,000, and by Dr. Haldane in the air of the Bristol sewers 20 per 10,000, as compared with 3 or 4 per 10,000 in the air outside. The excess of ammonia and organic matter found by Dr. Hurtley in sewer air was small, the figures being ·056 and ·014 parts per million respectively in sewer air and ·041 and ·008 parts per million in the air outside.

These results are practically identical also with those obtained by Professor Delépine in Manchester. He found that the amount of carbon dioxide in sewer air ranged from 6·7 to 17·2 parts per 10,000 volumes, as compared with a range of 3 to about 7 per 10,000 in the air outside, and that the amount of free ammonia was very small. Professor Delépine also ascertained that the air of a sewer, carrying ordinary domestic sewage, is free from any appreciable trace of methane or carbon monoxide, and that if one or other of these gases is present in sewer air, it must be due to the admission of coal gas or of the products of combustion into the sewer.

Sulphuretted Hydrogen.

63. There is, however, one very dangerous gas which may be present in a sewer under certain circumstances, namely sulphuretted hydrogen, and some years ago Sir Benjamin Richardson expressed the opinion that this gas is the "true disease-producing agent" in sewer air. Distinct effects on the human being may be produced by very small quantities of sulphuretted hydrogen, even, it is said, when it is present in air in the proportion only of ·05 parts per cent., and Dr. Haldane is of opinion, as the result of his investigations, that it is this gas which has been responsible for most of the fatal accidents which have occasionally occurred among men engaged in work inside sewers. In these occurrences, the gas usually produces more or less sudden insensibility in the person affected, with the result that he may fall into the sewage and be drowned.

Usually, however, this dangerous gas is not present in the air of sewers. Neither Dr. Haldane nor Dr. Hurtley discovered it in the air of the sewers examined by them, although these included unventilated sewers in Bristol, and the sewers in Hampstead which came to be investigated expressly on account of offensive effluvia from their manhole covers in the streets. The same negative result was obtained by Professor Delépine in Manchester, although in one experiment as many as 2,738 litres of sewer air were used, and were spectroscopically examined. The absence of sulphuretted hydrogen from sewer air is not so surprising as it seems, for, as Dr. Hurtley explained, the solubility of this gas in water is so great that, unless sewage is stagnant and undergoing rapid decomposition, it is not produced in sufficient quantities to be given off to the air.

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* Air of Sewers in Dundee and Westminster, by Professor Thomas Carnelly, D.Sc., and J. S. Haldane, F.R.S., M.A., M.D.—Proceedings of the Royal Society—Vol. XLII., p. 501—1887.

† Air of Buildings and Sewers, by J. S. Haldane, F.R.S., M.A., M.D. Transactions of the Sanitary Institute, Vol. IX.—1887.

‡ Report on Bacteriological and Chemical Investigations of the Sewer Air of Hampstead, by F. W. Andrewes, M.D., F.R.C.P., D.P.H., and W. H. Hurtley, D.Sc.—1905. [Published by the Borough Council of Hampstead for private circulation.]

§ Report to the Sewer Ventilation Committee upon the Effects on Health of the Air of the High Street Sewer in Manchester, by A. S. Delépine, M.Sc., M.B.—1909.

64. It is unlikely, therefore, that if sewer air, as distinct from drain air, contains any "true disease-producing agent," it can be attributed to sulphuretted hydrogen. On the other hand, it may be mentioned, Dr. Haldane has found that sulphuretted hydrogen is given off, in sufficient quantity to cause symptoms of poisoning in animals exposed to it, from the traps of house drains in which sewage is apt to be retained, such as large grease traps.

65. It has been shown nevertheless that, in exceptional circumstances, sulphuretted hydrogen may be present in the air of sewers, especially in large sewers or near outfalls where sewage may collect and remain stagnant for considerable periods. It is doubtful, however, whether it could pass *viâ* a house drain into a dwelling in sufficient quantities to be dangerous. Dr. Haldane pointed out that the gas would be so enormously diluted by the time it reached the interior of the dwelling that there would be no danger of sulphuretted hydrogen poisoning. This view is confirmed by the very exceptional case of St. Helens, where, owing to the nature of trade effluents discharged into sewers, there are active chemical changes in the sewage accompanied by evolution of sulphuretted hydrogen. There does not appear to be evidence that dangerous effects follow from the entry of this gas into house drains, although in St. Helens the sewer air is so offensive from the presence of this gas that it is necessary to confine it as much as possible to the sewers. Sewer ventilators at the street level have had to be closed, and the smell of sulphuretted hydrogen is so perceptible, even when discharged at a height, that sometimes the ventilating shafts of house drains directly connected with the sewer have proved a nuisance, to abate which it has been necessary to insert intercepting traps. Nevertheless, many house-drains in this town are not provided with intercepting traps.

The Smell of Sewer Air.

66. As regards the smell of sewer air, it follows from the foregoing that usually it cannot be due to sulphuretted hydrogen. Dr. Haldane and Dr. Hurtley agreed that it was due to the presence of minute quantities of a variety of volatile substances, such as indol, skatol, the mercaptans, and compound ammonias, which could not be detected by chemical test in the volumes of air dealt with. Dr. Hurtley is further of opinion that, in the case of the Hampstead sewers, the smell arose probably, not from the sewage at all, but from the decomposing moulds and fungi on the walls of the sewers.

It appears to be doubtful whether the smell of sewer air is usually more offensive than that of drain air, some witnesses contending that the most offensive portion of a drain or sewer system is the soil pipe, sink waste pipes, and internal traps of the house drain, while others were of opinion that drain air is usually inoffensive compared with sewer air. There seems to be no doubt that untrapped waste pipes of sinks and lavatories, discharging into the open air, even those which are of short length, may be the cause of serious nuisance inside the dwelling, and that such pipes, on this account, need to be provided with efficient traps close to the fittings to which they belong.

67. The offensiveness of sewer air, however, is sometimes pronounced. It varies greatly in different sewers, and, from time to time, in the same sewer. The causes of this offensiveness appear to be very difficult to determine. Some think that it is directly dependent on the intercepting trap, but whatever the cause or causes may be, ventilation of the sewer seems to have little or no effect upon it. Indeed, in some cases, increased ventilation, if provided at the street level, appears to aggravate the nuisance, merely because the number of openings at which the smell may be perceptible is increased. A common method of dealing with an offensive sewer is, not to increase the number of ventilation openings but to substitute ventilating shafts for openings at the street level, and usually this method is quite successful in dealing with such a nuisance. But in some cases, when trade effluents cause the sewage to be exceptionally offensive, ventilating shafts have to be reduced to a minimum or even abolished, as in the case of St. Helens already referred to. In Burton-on-Trent, again, sewer air is very offensive, because the sewage consists largely of effluents from breweries, and in the central parts of this town it has also been necessary to close all ventilating openings in the sewers, whether at the street level or at a height.

Importance of Smell.

68. The fact that sewer air frequently has a characteristic odour, though clearly not so important as if it had been found, habitually, to contain an excess of irrespirable or poisonous gases, demands, nevertheless, serious consideration. In this connection, it must be remembered that it is possible, through the sense of smell, to induce distinct modifications in physiological processes, so that something of more than mere sentimental or æsthetic importance is at stake. Indeed, it may be thought that the instinctive repugnance, which many people experience, to emanations from drains and sewers, is a manifestation of the natural defensive forces of the body. The smell of offensive sewer air is undoubtedly very unpleasant and destructive of ordinary comfort, and there seems to be no reason to doubt that it may produce definite ill-health. Moreover, some persons are extremely sensitive to distinctive odours of various kinds, not only to those emanating from sewage and sewers, but also to those of quite different origin. Dr. Ballard demonstrated this in 1876, in his report to the Board on offensive businesses,* and Dr. Haldane in his evidence instanced the effect, on some people, of the smell of coal gas, and of the smell which is often apparent in electric tube railways. In regard to sewer air Dr. Haldane expressed the opinion that, if it possessed no smell, it would not " do the least harm or cause ill-health."

69. From the chemical point of view the problem is narrowed down to the question whether, under ordinary circumstances, as well as under exceptional circumstances, it is necessary to exclude sewer air from the house drain on account of its smell, or what amounts to the same thing, whether sewer air is likely to be more perceptible, or less perceptible to the senses, when intercepting traps are present, than it is when they are absent.

The experience of East Grinstead and other places suggests that in ordinary circumstances, the absence of intercepting traps tends to make sewer air not more, but less, perceptible to the senses. In East Grinstead there are no sewer openings at the street level, and there are practically no intercepting traps; and the Medical Officer of Health states that he has " never had a complaint of smell or nuisance from a house ventilating shaft yet," although previous to the closure of street manhole covers, there had been serious nuisance from the escape of sewer air. On the other hand, the experience of places like St. Helens and Burton-on-Trent suggests that, in exceptional circumstances, it may be necessary to provide intercepting traps, expressly to prevent sewer air from becoming evident to the senses, for the same reason that it is necessary to close as many as possible of the ventilating openings in the sewers.

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* Report to the Local Government Board on " Effluvium Nuisances arising in connection with various Manufacturing and other Branches of Industry," by Dr. Ballard, published in the Medical Officer's Annual Report. Appendix VI, p. 113—1876.

PART IV.

BACTERIOLOGY OF SEWER AIR.

70. The bacteriology of sewer air has been the subject of many investigations, and, in one respect the results obtained have been practically uniform, namely, in showing that notwithstanding the immense number of microbes in sewage, the number to be found in sewer air is extremely small. This has been established alike by the first as well as by the most recent investigations, among others by Miquel in Paris, 1883-1899, by Uffelmann in Russia in 1886, by Petri in Berlin in 1887, by Haldane and Carnelley in Westminster, Dundee and Bristol in 1887, by Robertson in Penrith in 1888, by Laws in London in 1892, by Andrewes in London in 1905, by Delépine in Manchester in 1908, and by Winslow in Boston, U.S.A., in 1909. Most investigators are also unanimous that the number of microbes to be found in sewer air is usually less than the number to be found at about the same time in the atmosphere outside the sewer.

Thus, the mean of the observations, made by Dr. Haldane and Professor Carnelley in Westminster and Dundee, showed that there were about 9 microbes per litre of sewer air, as compared with about 16 microbes per litre of air outside. In dwelling rooms and in school rooms they found from 9 to 150 microbes per litre of air.

In unventilated sewers in Bristol, Dr. Haldane found 2 to 8 microbes per litre of sewer air, as compared with 13 per litre of air in the street.

Mr. Parry Laws also found, in the majority of his observations in a main sewer under the Green Park, Piccadilly,* that there were fewer micro-organisms in sewer air than in fresh air, although the mean of all his observations showed a slight excess in the former, viz. : 6 per litre of sewer air as compared with 5 per litre of fresh air.

Dr. Andrewes made one observation in the sewer in Hampstead from which offensive emanations were complained of, and found only 1 microbe per litre of sewer air, as compared with 3 per litre of air outside.

Professor Delépine, in Manchester, found that the number of bacteria, growing at 20 deg. C. on gelatine plates exposed simultaneously, for two hours, in a sewer and in a neighbouring garden was the same (10), although the moulds collected from sewer air (16) were more numerous than those collected from the garden air (13). The average numbers of bacteria, growing at 37 deg. C. on lactose agar plates, in 40 simultaneous observations, of about 100 minutes duration each, were 1·1 for sewer air and 2·2 for garden air.

Professor Winslow found in Boston, U.S.A.,† using the same method of exposing plates simultaneously in a main sewer and in the street above, that the microbes collected from the fresh air were about three times as numerous as those collected from the sewer air.

The source of Microbes in Sewer Air.

71. Many of these investigators have arrived at the conclusion that microbes found in sewer air are derived not from the sewage at all, but from the air outside the sewer. In the investigations made by Dr. Haldane and Professor Carnelley, such examination of the growth of micro-organisms as was possible at that date led them to the conclusion that, in the main, the micro-organisms of sewer air were the same as those found in the atmosphere, and that in both a large proportion consisted of moulds. They also found that the number of microbes in sewer air rose and fell with the number of microbes in fresh air; that with increased means of sewer ventilation the number of microbes in sewer air also increased; and that the number of sewer air microbes diminished as the distance from ventilation openings into the sewer increased. The only exception to these results was obtained in samples of sewer air obtained where more or less splashing of sewage was taking place.

72. Mr. Parry Laws was even more definite in his conclusion that "micro-organisms in sewer air are related to the micro-organisms in the air outside and not to the micro-organisms of the sewage." His observations showed again that the fluctuations in the number of sewer air micro-organisms corresponded with the fluc-

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* First Report to the Main Drainage Committee of the London County Council on Sewer Air Investigations, by J. Parry Laws, F.I.C.—1892.

† Massachusetts Institute of Technology. Contributions from the Sanitary Research Laboratory and Sewage Experiment Station. Vol. V., Boston, Mass., 1909.

tuations in the number of fresh air micro-organisms; that in a filthy unventilated sewer with "very heavy deposit," although the sewer air contained a large proportion of carbon dioxide, it contained very few micro-organisms indeed, about $1\frac{1}{4}$ per litre; that the micro-organisms of sewer air and of fresh air, as judged by their cultural and microscopic characters, were the same; and that there was an absence in sewer air of *b. coli.*

Dr. Andrewes was associated with Mr. Laws* in a subsequent investigation of the bacterial contents of sewage, from which they formed the conclusion, based on the absence of moulds from sewage and their constant presence in sewer air and fresh air, together with the absence from sewer air of micro-organisms which they found to be predominant in sewage, that "there is no relationship between the organisms of sewer air and sewage."

73. In 1905, Dr. Andrewes modified the above conclusion, as the result of his examination of the air of the Hampstead sewers already referred to. For the first time he succeeded in isolating a typical *b. coli* on a plate exposed in a sewer, but the significance of this result was impaired because he also found a typical *b. coli* on a plate simultaneously exposed in the fresh air outside the sewer. In a subsequent experiment he isolated an atypical *b. coli*, which did not appear in the corresponding plate exposed to fresh air, and to this result he attached greater importance.

It was mainly, however, the characters of *streptococci* found by him in sewer air which caused him to modify his previous conclusions. By exposing broth plates simultaneously in the sewer and in the street outside, he recovered several strains of *streptococci* from both, and on comparing their reactions to fermentation tests with those of *streptococci* derived from Hampstead sewage, he found that the sewer air *streptococci* resembled the sewage *streptococci* more closely than they resembled the fresh air *streptococci*. The number of *streptococci* examined in each case was necessarily small,† and, moreover, half of those recovered from fresh air appeared to be identical with those previously described by Dr. Houston as occurring in human fæces. The latter fact, as Dr. Andrewes points out, renders "comparison of the three sets of *streptococci* from this point of view of much less significance than would otherwise be the case." Furthermore, more than one observer has urged the need of caution in accepting, or has questioned the value of fermentation tests, for the purpose of differentiating between allied species of bacteria.

74. The most recent investigators, Professor Delépine and Professor Winslow, have again arrived at the conclusion that sewer air microbes are mainly those of the outside air. Professor Delépine's observations on the air of a Manchester main sewer, carried out systematically and continuously for upwards of a year, showed that sewage bacteria are very scanty in sewer air. He preferred to rely in this connection on examination for *b. coli* rather than for *streptococci*, and he found that of several thousands of bacteria, collected by him from sewer air, only six proved to be typical *b. coli*. Bearing in mind the large proportion of *b. coli* to other bacteria (at least 1 to 20) present in sewage, Professor Delépine claims that if sewage were, to any marked extent, the source of sewer air microbes, there should be at least one *b. coli* in every 50 or 100 bacteria found in sewer air.

Again Professor Delépine found that although microbes are readily collected from sewer air on plates facing upwards, the result is very different when the plates are turned downwards, so that the medium is exposed only to particles moving upwards from the sewage. Four out of six plates, so turned downwards, remained sterile though exposed to sewer air for one to two hours, and only one or two colonies grew in each of the other two, while on corresponding plates simultaneously exposed with the medium facing upwards the average number of colonies on each was 43. The presumption, therefore, in Professor Delépine's view, is that there is no giving off of bacteria from the surface of sewage flowing along a sewer.

75. Professor Winslow concluded from his investigations in Boston, U.S.A., that, in regard even to bacteria, in sewer air, which may be of intestinal origin,

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* Report to the Main Drainage Committee of the London County Council on the Result of Investigations on the Micro-organisms of Sewage, by F. W. Andrewes and J. Parry Laws—1894.

† 9 were derived from sewage, 13 from sewer air, and 16 from fresh air.

the principal source is not sewage but street dust. Plates, on which coliform microbes grow as red colonies, were exposed at varying heights above sewage, on a flight of steps in a street manhole of a main sewer, and he found that both the total microbes growing at blood heat, as well as those which formed red colonies, were, on the whole, more numerous on the plates placed on the higher than they were on those placed on the lower steps. On the top step, nearest the street and the most remote from the sewage, the colonies were so numerous as to be uncountable.

Summary of Bacteriology of Sewer Air.

76. This accumulated bacteriological evidence, which exhibits very few discrepancies, establishes the essential fact that the number of micro-organisms in sewer air is extremely small. This is established not only in the case of good sewers and those which are well ventilated, but also in the case of bad sewers, even those containing more or less stagnant sewage with much deposit, and those in which ventilation is small or absent. Indeed, it is in the latter kind of sewer that the number of sewer air microbes would appear to be at a minimum.

It seems also clearly to be established, not only that the bulk of the bacteria of sewer air are derived from the atmosphere, but also that bacteria of sewage origin, that is those that may be pathogenic, are very rarely present in sewer air, and that when their presence can be detected at all, their number is very small. In this respect the older investigations, such as those of Dr. Haldane and Professor Carnelley and of Mr. Parry Laws, have not been seriously shaken by the most recent investigations. Moreover, as will appear presently, it is probable that the occasional presence of sewage organisms in sewer air is dependent on splashing.

PART V.

BACTERIOLOGY OF DRAIN AIR.

77. The bacteriology of drain air has been studied within recent years by Major Horrocks*, R.A.M.C., in Gibraltar; by Dr. Andrewes and by Dr. Renney in this country; and by Professor Winslow in America. The three first named gave evidence in this inquiry.

Major Horrocks' Investigations at Gibraltar.

78. The investigations of Major Horrocks, were reported in a paper communicated to the Royal Society;† and included many observations with experimental arrangements of drain pipes and artificially inoculated samples of sewage, as well as with drains in actual use. The experimental installation of drain pipes was a very short one, comprising, generally, two 6-inch stoneware pipes, attached to either end of a 6-inch intercepting trap, and three or four drain pipes attached perpendicularly to the air-inlet of the trap. In the experiments, plates were suspended in the perpendicular pipe, and Gibraltar sewage, mixed with culture of *b. prodigiosus* or of *b. typhosus*, was poured into the upper end of the horizontal drain. After flowing through the pipes and trap, the sewage was collected at the lower end of the drain, and then re-passed through the pipes and trap, this process, in some experiments, being repeated over and over again. Major Horrocks was satisfied that accidental contamination did not take place.

Major Horrocks found, in his results, that whether the quantity of the test cultures was large or small, and whether the exposure of the plates was for 24 hours or for 20 minutes, colonies of the test microbe always appeared on the plates exposed in the perpendicular pipe, even on those which were placed nearly 12 feet above the level of the sewage in the intercepting trap. The number of test colonies thus found in any of these experiments was not recorded.

At a previous stage of his investigations Major Horrocks had found in experiments, "repeated again and again," in which sewage, mixed with the same test microbes, was shaken up in a closed jar until a "layer of bubbles formed on the surface," that plates exposed at a height of only 4 inches from the sewage, remained quite sterile. Stale sewage bubbling with gases of decomposition gave similar negative results.

Major Horrocks, in his evidence before us, suggested in explanation of these results, that in the closed jar there was no current of air, and that therefore, bacteria, even if they were ejected from the sewage, did not rise 4 inches, while in the drain experiments, currents of air could pass from the mouth of the drain to the top of the perpendicular pipe, and convey bacteria given off from the sewage to the distance stated. In one of the latter experiments, however, the arrangements were so modified that an appreciable current of air was barely possible, for the inlet of the intercepting trap was closed and plugged and the top of the perpendicular pipe was covered loosely with a glass plate, but, nevertheless, when typhoid stools were passed "slowly" through the trap, colonies of *b. typhosus* were found on a plate suspended in the perpendicular pipe about 3½ feet above the trap. The splashing, which results from the passage of sewage through an intercepting trap (par. 88) seems to be a more probable explanation of the results obtained.

79. In his experiments on drainage systems actually in use, Major Horrocks used *b. prodigiosus* as the test microbe. In one of these, a culture of this microbe was poured into and flushed through the water closet of a private house, and, in the result, the microbe was found on plates exposed not only in the various inspection chambers of the drain, but also on a plate exposed in front of the air-inlet of the intercepting

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* Now Lieutenant-Colonel Horrocks.

† Proceedings of The Royal Society, Series B., Vol. 79, No. B. 531, p. 255. "Experiments made to determine the Conditions under which "Specific" Bacteria derived from Sewage may be present in the Air of Ventilating Pipes, Drains, Inspection Chambers and Sewers," by Major W. H. Horrocks, R.A.M.C., 1907.

trap, although the latter was provided with a mica flap valve to prevent its action as an outlet.

In a similar experiment with a basement water closet at a hospital, the test microbe was found on a plate exposed at the top of the soil pipe about 50 feet above the ground, and about 60 feet from the sewage. As will appear later (par. 96) a similar experiment by Dr. Andrewes also yielded positive results.

80. The most striking experiment was one, also at this hospital, in which plates were exposed at a variety of places where it was expected that the microbe would be found, viz., the top of the soil pipe, the intercepting trap chamber of the drain into which the soil pipe discharged, several inspection manholes of the sewer both above and below the spot where the drain discharged into it, and the top of a 6-inch ventilating shaft on the sewer; and also in two places where it was supposed that the microbe could not be found, viz., the intercepting trap chambers of two adjoining drains connected with the same sewer. In the result the test microbe was found on all the former series of plates, but, contrary to expectation, it was also found on one of the plates exposed in adjoining intercepting trap chambers, and, ultimately, the stopper of the raking arm was found to be missing in that particular chamber, so that the drain was not intercepted from the sewer as had been supposed.

In the above experiments on drains actually in use, all the plates were left in position for 24 hours, but no particulars are available as to the number of test microbes recovered in any of them.

Dr. Andrewes' Investigations.

81. The investigations made by Dr. F. W. Andrewes into the bacteriology of drain air were carried out for the Local Government Board, and are fully described in the annual reports of the Medical Officer of the Board for 1906-7 and 1907-8. The experiments were conducted in drainage systems in actual use at St. Bartholomew's Hospital in the City of London and at a private house.

In the first place, Dr. Andrewes pursued the line of investigation he had adopted in examining sewer air in Hampstead, and compared the reactions, to fermentation tests, of *streptococci* and *b. coli* in drain air, with those recovered from fresh air and from sewage. These tests indicated that the microbes belonging to these two groups, recovered from drain air, resembled those of sewage more closely than those of fresh air.*

82. In the course of these investigations, Dr. Andrewes was impressed by the want of uniformity of his results, for sometimes the bacteria recovered from drain air were very numerous and sometimes very few, and in subsequent experiments he endeavoured to ascertain the reasons for this discrepancy. For this purpose plates of a medium on which lactose-fermenting bacteria of the *b. coli* group grow in characteristic red colonies, were exposed, simultaneously, in various inspection chambers of the hospital, on four different occasions. The results were very irregular and confusing, for on each occasion, numerous red colonies developed on some plates, while several other plates were wholly negative. Furthermore, plates exposed at the same spot on all four occasions showed sometimes many, sometimes few, and sometimes no red colonies at all. Dr. Andrewes then selected two inspection chambers from which he had recovered numerous red colonies, and exposed successive plates in them, each for one hour only, from 5 a.m. until 11 p.m. The results showed great differences, the number of red colonies being numerous in the morning and evening, but relatively very

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* Thus, of 65 strains of *streptococci* obtained from fresh air in the city of London about 66 per cent. were of the type he terms *equinus* (because it is indigenous in horse dung), while 34 per cent. belonged to types believed to be of human origin (*mitis*, *salivarius*, and *fæcalis*). On the other hand, of 19 strains obtained from sewage (including 9 from Hampstead) 5 per cent. only were of the *equinus* type and 95 per cent. were of the human types mentioned (58 per cent. *salivarius*), while of 6 strains recovered from the air of the main drain at St. Bartholomew's Hospital all proved to be of human type (*salivarius*). Of 13 strains obtained from Hampstead sewer air, 8 (61 per cent.) were *salivarius* and 5 (38 per cent.) *fæcalis*. As regards *b. coli*, seven plates exposed to fresh air on different occasions, usually for an hour, yielded only three microbes of the *b. coli* group, and none of these proved to be typical *b. coli communis*, although one was probably an atypical *b. coli*. Sewage of the hospital yielded numerous colonies of the *b. coli* group, but of 10 of these which were selected for further test none proved to be typical; four proved to be atypical; and the remainder were examples of other members of this group. Plates exposed in the main drain of the hospital near the intercepting trap did not always succeed in recovering coliform microbes, but on some occasions large numbers were obtained. Of 42 of these selected for further examination, 10 did not belong to the *b. coli* group at all, four were typical and three atypical *b. coli*, and the remainder were other members of this group.

few in the intervening hours. Another hour by hour experiment carried out at a private house gave similar results.*

Splashing of Sewage in Drains.

83. Dr. Andrewes' observations during these experiments made it clear that the occasional presence, in large numbers, of red colonies on his plates was determined by the discharge of fæcal matter into the drain, and that their relative abundance or the reverse, on these occasions, was determined by the amount of splashing or agitation of the sewage in its course through the drain.

This conclusion was confirmed by experiments with *b. prodigiosus* discharged through a water closet in a hospital block, 60 feet above the ground level, a plate being suspended in the inspection chamber at the foot of the soil pipe into which it discharged. As much splashing as possible was produced in the drain by repeated flushing of the water closet in which the test culture was placed, and by turning on all available sink taps. In the result no fewer than 1,500 colonies of *b. prodigiosus* were found on the plate exposed at the foot of the soil pipe.

In another experiment of this kind, carried out at a private house, the splashing produced was considerably less than in the previous experiment, the water closet selected being on the ground floor, and the inspection chamber into which it discharged being some distance (15 feet) beyond the foot of the soil pipe. A plate exposed in this chamber showed 92 colonies of *b. prodigiosus.*

Duration of Effect of Splashing.

84. Subsequently, Dr. Andrewes repeated these experiments with a view to ascertain for what length of time splashing was likely to cause the presence of bacteria in drain air.† In one experiment, at the hospital, successive plates were exposed in an inspection chamber, each for five minutes during an hour, and it was found that the test microbe was present only on the plate which had been exposed during the actual flushing of the water closet. Plates exposed before, and every five minutes for an hour after the flushing, were free from the test microbe. In the other experiment, at the private house, the time of exposure of each plate was even shorter, only 2½ minutes. On the first plate exposed, when the closet was flushed (repeatedly in this case), there were 38 colonies of the test microbe, but on the three following plates, only 1 colony, 2 colonies, and 1 colony, respectively, were found, while, during the subsequent hour, plates, exposed now for five minutes each, showed no colonies at all, except one which was exposed half an hour after the commencement of the experiment, when the closet was again flushed. On this plate a single colony appeared.

These experiments bring out very clearly that splashing is the cause of the presence in large numbers of sewage microbes in drain air, and that the effect of this splashing is instantaneous and extremely evanescent in its duration.

Dr. Renney's Investigations.

85. Dr. Renney described to us in his evidence some interesting observations which he carried out in Sunderland at the Infectious Diseases Hospital of that town. In one experiment, he exposed plates simultaneously for one hour in each of five inspection chambers on the drainage system of the hospital, one being the main inspection chamber through which all the sewage from the hospital passed, while two control plates were exposed to the air in the grounds of the hospital. On the controls and also on one of the drain air plates moulds only appeared, while another of the drain air plates remained quite sterile. On the remaining three plates a few colonies were found, but none of these belonged to the *b. coli* group. It is noteworthy that the drains of this hospital were discovered to have no intercepting traps and to be in uninterrupted aërial connection with the town's system of sewers.

Another experiment was carried out in the inspection chamber of the drain, into which the water closet of the typhoid fever pavilion discharges. Nine acute cases of typhoid fever were under treatment at the time, and typhoid stools were passed down the closet during "the whole time" of the experiment. Three plates were exposed from 9.45 a.m. to 11 a.m., and three from 11 a.m. to noon. On the first series of plates, no growth was found except two moulds, but on the second series, numerous colonies were found. Several of these proved to belong to the *b. coli* group, and one colony showed, on detailed examination, that it might be *b. typhosus.* The negative value of these experiments was diminished, however, by the fact that the typhoid stools, previous to their discharge into the drain, had been mixed with a disinfectant.

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* The plate exposed from 9 to 10 a.m. showed as many as 808, and that for the succeeding hour 34 red colonies, but of the remaining plates, 15 in number, seven showed no colonies at all, and the others showed very few, the number on each of these ranging from one to nine.

† Second Report on the Bacteria of Sewer Air and Drain Air, by F. W. Andrewes, M.D. Annual Report of the Medical Officer of the Local Government Board, Vol. 37, p. 266—1907-8.

Professor Winslow's Investigations.

86. From the nature of the experiments in the foregoing investigations, viz., the exposure of plates for more or less prolonged periods, the results obtained were largely qualitative rather than quantitative. Although it is important to know whether, under certain conditions, sewage bacteria may be detected in drain air, it is also important to know the proportion which such bacteria, when present, may bear to the volume of air passing through the drain; a point which was referred to by the Medical Officer of the Local Government Board in his annual report of 1907-8.

87. Professor Winslow's experiments, carried out at the Massachusett's Institute of Technology, were largely directed towards testing the question quantitatively.

Among other investigations, he examined the air in 19 different house drainage systems actually in use in Boston, U.S.A., in the following way. Selecting in each a suitable spot, either in a soil pipe (sometimes near the top, sometimes near the foot), or in a sink waste pipe, a hole was bored, and a glass tube, connected with two bottles containing suitable culture medium, was inserted, through which the drain air was then aspirated litre by litre. In all, 20 of these observations were made, and in each case 10 successive litres of air were drawn off from the drain, so that a total of 200 litres of drain air came under examination. Of these, only 48 litre samples of air contained bacteria capable of growing at blood heat, and in 41 of these the bacteria were proved not to be either *b. coli*, its allies, or *streptococci.* Moreover, of the 7 litre samples of air which proved to contain one or other of these micro-organisms, 3 were accidentally infected by the escape of sewage itself from the drain into the culture bottles during the experiment, so that Professor Winslow concludes that only 4 samples of drain air, out of 197, should be regarded as showing the presence of sewage bacteria.

At the time of these experiments the drains under examination were in ordinary use, and observations taken during them showed that while each of the 4 samples of drain air, which contained sewage bacteria, was collected, definite splashing of sewage had occurred in the drain. It is also noteworthy that the succeeding sample of air in each of these cases contained no sewage bacteria, a result which confirms those obtained by Dr. Andrewes as to the evanescent effect of splashing.

Bacterial difference between Sewer Air and Drain Air.

88. It is evident from the foregoing investigations that there is a material difference, bacteriologically, between sewer air and drain air, for while bacteria of sewage origin are rarely found in sewer air, and when found their number is very small; in drain air, on the other hand, not only are sewage microbes frequently found, but also, when present, their number may be very large.

While this general statement indicates, broadly, what is commonly characteristic of drain air in contrast with sewer air, it is subject to certain qualifications. For instance, Professor Winslow's experiments show that, although many sewage microbes may be collected on plates, exposed to drain air, for more or less considerable periods, the number of such microbes, when quantitatively estimated in relation to measured volumes of the drain air, is very small.

Again, it is scarcely open to doubt that the bacterial difference between sewer air and drain air is accounted for by the splashing which occurs in the passage of sewage in a house drain, especially when falling from a height or passing through a trap. Indeed, since the presence, in large number, of sewage microbes in drain air has been shown to be so directly associated with splashing of sewage in a drain, more especially by the investigations of Dr. Andrewes, the presumption is strong that, if there were no such splashing, sewage microbes would be as seldom present in drain air as in sewer air. It is obvious that sewage, flowing along a drain, is not likely to give up its microbes any more readily than sewage flowing along a sewer has been shown to be.*

It is also established by Dr. Andrewes' experiments that the presence of sewage bacteria in drain air, as the result of splashing, lasts only a very short time, and that they subside with great rapidity. The appearance of sewage bacteria after splashing is doubtless effected, not by the ejection or active disengagement from the sewage of the bacteria themselves, but by the detachment, from the splashing or disturbed sewage, of more or less minute drops of sewage. If the passage of sewage or water through an intercepting trap be watched, as, for instance, in an open experimental installation like that used in the Islington experiments, it will be observed that droplets are frequently thrown off from the liquid, sometimes to an astonishing distance. Besides these comparatively large visible droplets, there must be many so minute as to be invisible, and it is from such minute droplets that Dr. Andrewes concluded that the plates used in his drain air experiments were mainly infected. It is possible that the enclosure of microbes in droplets helps to explain their extremely rapid subsidence, which was such a striking feature of his experiments.

89. But, notwithstanding that the presence of sewage bacteria in drain air is subject to the foregoing reservations, the broad fact remains and must be accepted, as an essential practical point, that sewage bacteria are frequently present in drain air, although such bacteria are usually absent from sewer air.

Practical Importance of this Difference.

90. The practical importance of this essential bacterial difference between sewer air and drain air is very great.

One of the dangers feared from the omission of the intercepting trap is that pathogenic microbes, given off from sewage, may be wafted from the air of the sewer into the house drain, and thence into the dwelling itself. It is obvious, however, that if, as appears usually to be the case, micro-organisms of sewage origin are not present in sewer air, there can be no wafting of pathogenic microbes from sewer to drain as has been apprehended. It is, likewise, obvious that if sewer air contains, as apparently it does contain sometimes, such microbes of sewage origin, but so few in number that their presence can be demonstrated only with difficulty, the chance that they can be wafted into a house drain is very small, while the chance that any of them can pass further and enter the dwelling itself must be smaller still. Consequently, even if, in any particular instance, sewage microbes can gain admission into a house from the air of the drain belonging to it, the possibility that such microbes can include any derived from sewer air, if the intercepting trap is absent, must be very remote.

91. On the other hand, the bearing of the frequent presence of sewage bacteria in *drain air* needs to be clearly recognised.

It is contended, for instance, that an intercepting trap, though in no way operative as protection to a dwelling house from the entry of microbes derived from the air of the drains belonging to it, will at least ensure the house, however remote the chance of such an occurrence may be, from the entry of microbes (*viâ* the sewer) which may be derived from the sewage coming from the drains of other houses. But, clearly, the bacteriology of drain air shows that, theoretically, it is possible for a dwelling house to be invaded by microbes, derived from the drains of other houses, irrespective altogether of intercepting traps.

Thus, the air-inlet of a drain, as we have shown already, may act as an air outlet, and smell from it may affect persons other than those resident in the house to which it belongs. Again, the air outlet or ventilating shaft of a house drain may be so situated as to affect, so far as may be judged by smell, residents of houses other than those of the house to which it actually belongs. Therefore, it is conceivable that, in cases where the smell of drain air is wafted to persons other than the residents of the house by the drain, sewage microbes of drain air origin may be wafted to them also. It may be true that, though such a contingency is conceivable, it is only a remote possibility. On the bacteriological evidence, however, it can scarcely be denied that it is a less remote possibility than the wafting of microbes from sewer air to drains, and thence, in whatever way to the interior of the dwelling, since, in the latter case, microbes of sewage origin are seldom present in sewer air, while in the former case, microbes of sewage origin are frequently present in drain air.

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* Major Horrocks concluded from some of his experiments that sewage bacteria might be detached from the internal surface of drain pipes after they had become dried, but it is doubtful whether such drying as was effected artificially in his experiments can be anything but a rare occurrence under practical conditions in this country, while it is certain that in sewers there is always great humidity of the air and that their walls are always moist. In soil-pipes, however, particularly those exposed to the sun, there may be such drying.

92. In other words, while an intercepting trap may guard a house against a bacterial danger through the sewer which appears indeed to be almost non-existent, it does not exclude the possibility of drain air microbes finding their way, from one house to another, through other channels involving bacterial danger theoretically not inconsiderable. Indeed, it might not unreasonably be argued that in the ventilating shafts of house drains lies the principal bacterial danger, and that the free ventilation of house drains which is usually associated with the provision of an intercepting trap, is itself calculated to foster the dispersal of drain air microbes in the neighbourhood of houses. It might even be contended, on strictly bacteriological grounds, that any ventilation of house drains or the provision of any external openings in them is wrong, and constitutes a possible danger, since in the absence of air currents, brought about by ventilation, such microbes, however numerously suspended they may be in drain air as the result of splashing, must merely subside and remain in the drain itself.

We are not suggesting that this is a serious danger, although it is possible that it may have some importance in relation to sore throat and perhaps other illnesses. It is necessary, however, to make quite clear what is the logical outcome of the bacteriological evidence that microbes of sewage origin are frequently present in drain air and seldom present in sewer air. That the danger in question is probably not serious, seems to be indicated by the fact that, in the air of London, microbes of sewage origin can very rarely be detected, even after the exposure for many hours, in likely places, of plates coated with media specially designed to demonstrate their existence. It follows, however, that, if danger of this kind through drain air is not of importance, the danger that sewage bacteria of sewer air may find access into the interior of a dwelling *viâ* the drain, owing to the absence of intercepting trap, must be still more unimportant.

Experiments as to Passage of Sewage Microbes from Sewers into Drains.

93. Nevertheless, as one observer, Major Horrocks, found by experiment in Gibraltar that test microbes introduced into a sewer from a house drain may be recovered from another and neighbouring drain in direct aërial connection with the same sewer, we thought it desirable that further direct investigation should be made. When, therefore, Dr. Andrewes offered to make experiments suggested by us, in the course of his further observations for the Local Government Board on the bacteriology of drain air and sewer air, we asked him to include investigation on this point, especially as to the numerical extent to which such sewer air microbes might pass into drains.

In all, five experiments were made, one at East Grinstead and the remainder at Willesden, and they were all conducted in practically the same way. Agar plates were placed or suspended in the inspection chambers of several house drains, and in three of the experiments in the ventilating shafts also, while direct aërial communication of the particular drains with the sewer was effected by removing the stoppers from the raking arms of their intercepting traps. Nine litres of a rich broth culture of *b. prodigiosus*, containing, in each case, *several hundred millions per c.c.* of this microbe, was then poured steadily for an hour directly into the sewer to which the houses under observation drained. Care was taken that this massive infection of the sewer was effected without splashing at the point of introduction, but as much natural splashing as possible was sought to be effected in the sewer, during the experiment, by discharging water-closet flushing cisterns in the houses. It was satisfactorily shown also in each experiment that currents of air were passing from the sewer to some of the house drains and up their ventilating shafts.

94. *First experiment: negative*:—In the first experiment, at East Grinstead, although the drain inspection chambers, in which the plates were placed, were unusually close to (within 5 feet of) the sewer, the results were totally negative. The test microbe was not found on any of the plates exposed, 12 of which were placed in inspection chambers and 12 suspended in ventilating shafts of the house drains.

A sample of sewage obtained, after the experiment, from the infected sewer, was found to contain at least one million of the test microbe per c.c. The sewer in this case was small, being only 6 inches in diameter, while its gradient was slight (1 in 80), but the sewer connections were very steep. It was thought, however, that perhaps little or no splashing in the sewer was produced, and that, therefore, the conditions were abnormally favourable for a negative result.

Second experiment: positive:—In the next experiment, therefore, at Willesden (Guilsborough Road) a larger sewer (15 inches) and one of very steep gradient (1 in 33) was selected. In this case 47 plates were exposed in inspection chambers of house drains, but none could be suspended in the ventilating shafts as they were unfavourably situated. Plates were also suspended in two of the sewer manholes. The latter sewer air plates proved to be infected with small numbers of the test microbe (2 colonies on one and 17 on the other), and on eight of the 47 drain air plates, there were also a few colonies of the microbe, viz.:—13 on one, 4 on another, 2 each on two others, and only 1 each on the remaining four infected plates. A sample of sewage obtained from the infected sewer one hour after the experiment contained at least 100 of the test microbe per c.c.

In this experiment much difficulty was encountered in inserting the plates in and recovering them afterwards from the inspection chambers, some of which were very deep, and it was necessary for an assistant to climb down into the chambers for this purpose. As this assistant had, during the experiment, walked over the spot where some of the test culture, in the process of being poured into the sewer, had been spilt, it was possible that the plates were accidentally infected by him in the process of their recovery, although Dr. Andrewes was of opinion that the distribution of the colonies on them did not suggest it.

Third experiment: negative:—A third experiment was therefore undertaken also in Willesden (Crediton Road). Here the sewer was still larger (18 inches) emptying into one 2 ft. 3 in. by 1 ft. 6 in., while the gradient was also steep (1 in 60). In this experiment plates were suspended in the ventilating shafts, as well as in the inspection chambers, of 19 house drains. The results in this case were again totally negative, the test microbe being absent not only from the house drain plates but also from plates exposed in two of the sewer manholes. Moreover, the test microbe could not be detected in a sample of sewage which was obtained from the sewer one hour after the conclusion of the experiment.

Fourth experiment: negative:—It was thought desirable to repeat this experiment, in view of the absence of the test microbe from the sample of sewage, arrangements being made to take a sample, on this occasion, during, instead of after, the experiment. The sample of sewage, so obtained, contained at least 2,000 of the test microbes per c.c., but again none were found on any of the plates exposed in the house drain. The result of this experiment was therefore also quite negative.

Fifth experiment: slightly positive:—In view of the fact that three experiments had been totally negative, and that the only positive experiment was open to suspicion of accident, it was decided to repeat the experiment at Guilsborough Road, arrangements being made to suspend the plates in the inspection chambers, on this occasion, in order to avoid the possibility of accidental infection. At the conclusion of this experiment, and before the plates could be removed from the inspection chambers, a severe thunderstorm took place; and when, after the storm, the plates were recovered, it was found that sewage had backed up in the infected sewer and had flooded the plates suspended in it. Subsequent examination showed that this backed up sewage had risen in the sewer connections to within 15 inches of the inspection chambers, in which the drain air plates were suspended. Notwithstanding the disturbance both of sewage and of sewer air, which must have taken place in the sewer and in the sewer connections, all the drain air plates, 25 in number, were free from the test microbe except two, on each of which only a solitary colony appeared after incubation. A sample of sewage taken during the experiment contained several thousands of the test microbe per c.c.

95. These five experiments, even assuming that the first experiment at Willesden was not vitiated by accidental contamination, confirm, therefore, as conclusively as may be expected, the deduction to be made from previous observations establishing

the rarity of the presence of sewage microbes in sewer air, viz., that, under practical conditions, the chance of sewage microbes passing from sewer air to drain air is very small, and that their chance of passing further from the drain into the dwelling and thence into a human being must be still smaller. It needs to be remembered, moreover, as Dr. Andrewes has pointed out in his report* to the Board on these experiments, that the test microbe was present in the sewage to the number of hundreds per c.c., in one case, of thousands per c.c., in another case, and of at least a million per c.c., in another case, and that "no one has suggested that pathogenic bacteria are ever present in sewage in numbers approaching this."

96. In contrast with the results of these experiments, a further series made by Dr. Andrewes at St. Bartholomew's Hospital may be mentioned. On four successive days he discharged culture of *b. prodigiosus* from the water closet on one or other of the four floors of one of the hospital blocks, four 2-inch plates having been previously suspended, one above the other, inside the top of the soil pipe with which they are connected, and also a similar tier of plates in an adjoining pipe (constructed like a soil pipe) into which the sink wastes on each floor discharge. Both these pipes, open at the top, discharge below into a single inspection chamber provided with an intercepting trap, but not with an air-inlet, so that the two pipes referred to are the only available channels for air currents from or to the inspection chamber. On all four occasions Dr. Andrewes recovered the test microbe from both pipes, thus confirming the results obtained by Major Horrocks in a somewhat similar experiment (par. 79). On two occasions the number of the test microbes recovered was very small, in one pipe or the other, but usually it was considerable. Thus in the case of the soil pipe the numbers of test microbes were on the four days, 47, 153, 64, and 2 respectively, and in the case of the sink waste pipe, 34, 7, 127, and 118.

97. The results of these experiments emphasise the point to which we have already referred, namely, that the bacteriological evidence indicates that, if any bacterial danger exists at all in house drainage, it is to be found in the drain air that may escape from the outlets of ventilating shafts of house drains. But even this danger requires to be regarded in its true perspective, as we have pointed out (pars. 91 and 92).

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* Third Report on the Bacteria of Sewer Air and Drain Air, with special reference to the Conveyance of Sewage Bacteria by Air Currents, by F. W. Andrewes, M.D. Annual Report of the Medical Officer of the Local Government Board, vol. 40, p. 387.—1910-11.

PART VI.

GENERAL EVIDENCE.

98. Having now considered the physical evidence as well as the chemical and bacteriological evidence, it remains to consider other evidence, bearing on the belief that evil effects on human beings will result from the entry of sewer air into house drains. This belief is largely based on the assumptions, with which we have dealt in detail in the foregoing pages, that sewer air contains more pernicious effluvia or gases and more microbes of sewage origin than drain air. It is also based, however, on investigations from time to time of prevalences of disease, usually of epidemic type, the available facts and data of which seemed to bear the interpretation that sewer air had been a more or less important factor, sometimes indeed the predominant factor, in the dissemination or spread of such diseases.

99. In the earlier days of epidemiological investigation, it was common to attribute outbreaks of many spreading diseases to the influence of emanations from decaying animal matter, or of effluvia from drains and sewers. Indeed, as we have mentioned in the opening of our report, these influences were regarded at one time as being the most direct and commonplace of all agencies, by which such diseases were disseminated among human beings. But as first one and then another agency of disease came to be identified, it became less and less frequent to attribute disease to mere foul emanations, including those from sewers and drains. It has been suggested to us that this change has been the result, not so much of fallacious interpretation of facts by earlier observers, but of the careful and costly measures which have been taken, during the last 30 to 40 years, to protect the public from the influence of emanations from sewers and drains. At all events, although sewer air is not generally regarded in such a dangerous light as it formerly was, there is no doubt a considerable body of medical opinion which retains the view that certain diseases, notably typhoid fever, diphtheria, quinsy and sore throat, and certain "septic" diseases, are fostered or are even actually produced by exposure to sewer air or drain air.

On the other hand, many believe that if past prevalences of disease, attributed directly to sewer air could be re-investigated in the light of present knowledge, some other explanation of the facts ascertained would be patent, and that emanations from drains and sewers, though they may be extremely objectionable to the senses and harmful in the same way that any offensive air may be, are not the cause and do not foster the spread of any disease.

Thus Dr. Haldane expressed the opinion in his evidence, that the theory of sewer air infection was based on "worthless evidence," and that as a general rule "illness was put down to sewer air if the cause was unknown," particularly so "at the time when the influence of water and of milk and of personal infection was really not understood." He was even "very suspicious of the theory" that sewer air, apart from its smell, can be a predisposing cause of disease.

100. It is clearly impossible to prove, by direct evidence, either the one proposition or the other—either that emanations from sewers were actually the cause of epidemic illness in the past and would be so again if opportunity offered; or that these conclusions were wrong and that such emanations do not cause epidemic illness. Nevertheless, it may be said that it is by no means the case, at the present time, that opportunity does not exist for sewer or drain emanations to foster disease if they are capable of doing so, and that our present knowledge as to the influence of personal infection, of infected water, of infected food, of infected dust, and so forth, does afford presumption that some at least of the conclusions of the earlier investigations may have been erroneous.

Sewer Men.

101. There is, however, much indirect evidence in connection with the influence of sewer air which indicates very plainly that it is not so dangerous as has been supposed. For instance, persons deliberately exposed to the air of sewers rarely suffer ill effects. There does not appear to be definite evidence that men, whose employment it is to work about or inside sewers, suffer unduly from either general ill-health or from such diseases as enteric fever or those that are designated "septic."

It has been suggested that this negative evidence is not worth much, on the grounds that men who are so employed are a special class selected for their robust physique, and that they become "acclimatised" and therefore immune to the ill effects, whatever they may be, of sewer air. But there appears to be little evidence in support of these contentions. The witnesses whom we questioned on this point were, for the most part, officials, who are actually responsible for the selection of sewer men to work under their supervision, and they informed us that special inquiries as to health or robustness of applicants for such work are not usually made, and that in these respects there is no reason to regard them as a class specially above the average working man. One witness informed us that any inquiries he made were directed merely towards ascertaining the trustworthiness of the men employed, so that they could be relied upon to do full work in the absence of constant supervision. It needs to be remembered, moreover, that a robust physique or robust general health does not always afford protection against such diseases as are in question.

It appears also to be difficult to obtain evidence that sewer men become "acclimatised" to their work, or, at any rate, that, when they first take to this form of employment, some of them discover that it is prejudicial to their health and that they must give it up.

102. The negative evidence as to sewer men is confirmed, in a striking manner, by the testimony of the bacteriological, chemical and other observers who, in the course of their investigations, have been obliged, for the first time in their lives, to enter sewers and in some cases to remain in them for considerable periods of time. So far as we know there is not a single instance, certainly not among those who gave evidence before us, of any ill effect produced by such unaccustomed incursions into sewers; whether in the case of Dr. Haldane who examined unventilated sewers in Bristol and foul sewers in Dundee; in the case of Mr. Laws who examined foul sewers in London; or in the case of Dr. Andrewes and Dr. Hurtley who were called upon to investigate sewers in Hampstead on account of offensive emanations from them. Professor Delépine also reports that neither himself nor any of his assistants suffered any ill effects during their prolonged investigations in Manchester.

103. It has been contended that sewer air, even assuming that there is no evidence of ill effect when breathed in a sewer, is likely to be injurious when it escapes into a confined space, as for instance into the room of a dwelling. It is difficult to conceive, however, that escape of sewer air into a room can produce more serious consequences than sewer air breathed *en masse* in the sewers themselves, unless it is the case that diluted sewer air is more harmful than sewer air which is undiluted.

Experiments on Animals.

104. Two observers have made direct experiments on animals with a view of throwing light on this question,—Dr. Guiseppe Alessi* and Professor Delépine.

Dr. Alessi sought to ascertain whether animals—rabbits, rats and guinea-pigs—became more susceptible to certain pathogenic microbes with which they were experimentally inoculated, "if put to breathe in surroundings defiled by putrid gases." For these experiments he used attenuated strains of microbes of the *typhosus* and *coli* groups, and he found that such microbes were much more virulent with animals which had been exposed to "putrid gases" than with control animals not so exposed. The total number of animals subjected to the putrid effluvia was 179 and of these 143 or 80 per cent. died after inoculation with the microbes referred to; while of 133 control animals similarly inoculated only 3 or 2¼ per cent. died. In another set of experiments he allowed animals to breathe air mixed with one or other of the gases which may be given off from decomposing organic matter, and he found that the effect of these gases, individually, was not nearly so pronounced as those of the previous experiments. Dr. Alessi concluded from his investigations that inspiration of putrid gases predisposed the animals he used to the pathogenic action of the microbes he employed, and that this effect was due to the combination of gases given out by putrid fermentation rather than to any one gas in particular.

The value of experiments of this kind depends on the conditions under which they are carried out, and on the care taken to ensure that the control animals except in the given particulars are kept under exactly the same conditions as the experimental animals. Dr. Alessi's description of these conditions is as follows:—"The rats "were exposed to the exhalations from a closet, untrapped . . . in a box whose "lower side, made of a network of metal, closed the aperture of the closet. The "guinea pigs and rabbits were kept in a case whose bottom was also formed of a "metal network, under which was placed a vessel in which were excrementitious "substances. The animals were fed in the same way as others kept in a normal con- "dition." It was assumed, in the case of the rats, that, as the closet was untrapped, the animals were exposed to sewer air, but although they must have been exposed to effluvia from the soil pipe or drain immediately below the closet, no proof is adduced that the animals were in fact subjected to the effects of sewer air at all. Moreover, the exact conditions under which the control animals were kept is not described, beyond the statement that they were "kept in a normal condition" and were "fed in the same way" as the experimental animals.

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* Researches by Dr. Guiseppe Alessi—"On Putrid Gases as Predisposing Causes of Typhoid Infection"—Translation—Published in the Journal of The Royal Sanitary Institute, Vol. XVI., Part IV.—1896.

105. Professor Delépine's experiments on animals were carried out in connection with the investigations into the bacteriology and chemistry of the air of a main sewer in Manchester, already referred to. He had constructed, specially for the purpose, two adjoining rooms, similar in every respect, except that in the one the air supply was solely drawn from the interior of a main sewer, while in the other it was solely drawn from the air of a garden. In these rooms, in two precisely similar cages, animals were kept, the air supply being so arranged that the volume and velocity of fresh air and sewer air passing through each cage was always the same. While the animals were in these cages they had no other air supply than sewer air in the one case and garden air in the other.

During these experiments marked changes occurred in the flow and character of the sewage in the sewer under observation, as well as in the chemical and bacterial composition of the sewer air; in fact, according to Professor Delépine, "the sewer "was at its worst, and subject to the greatest amount of disturbance." Further, the experiments extended over the hottest and coldest seasons, and other meteorological conditions underwent a great range of variations.

The animals used in these experiments were cats, rabbits, and guinea pigs, and, in nine different series, either very young animals, adult animals, or diseased animals were under observation, the duration of exposure in the experimental cages ranging from 7 to 83 days. Daily records were kept of the weights of the animals, as well as of the quality of sewer air and fresh air respectively passed into the cages.

The net result of the experiments was, to quote Professor Delépine's report, that "no material difference could be observed between the animals, healthy or "diseased, that had been exposed to equal amounts of sewer air and of pure garden "air," while "a careful comparison of the rate of growth of young or adult, healthy "or diseased animals does not bring out any marked or constant difference." Professor Delépine's summary table of his experiments, as well as one of his charts, are reproduced in Appendix V. (p. 76).

It so chanced that, towards the end of these experiments, the animals under observation were attacked by severe illness, due to infected food, which caused death in several of them, but the relative mortality among sewer air animals and garden air animals proved to be practically identical. Professor Delépine points out that "this "accident . . . . proved advantageous owing to the fact that animals exposed "to sewer air and garden air were equally affected . . . and gave . . . the "opportunity of comparing the effects of sewer air and of ordinary air on animals "that had contracted *naturally* a fatal disease."

The value of Professor Delépine's experiments is greatly enhanced by the exactness with which they were carried out, as well as by the fact that the animals were definitely exposed to sewer air alone, and not, as in Dr. Alessi's experiments, to the concentrated effects of putrefying excrementitious substances.

Association of Disease with Drain Defects.

106. In the investigations, to which we have already referred, in which there had appeared to be direct causal relation between disease in human beings and exposure to sewer air or drain air, it is probable that this supposition has often been based on the frequent association of disease with drain defects. It is a common routine practice to examine the drainage systems of houses on the occurrence therein of the more important infectious diseases, and the frequency with which this has revealed

the existence of drainage defects, permitting of the possible entrance into the house, sometimes of drain air alone, sometimes of drain air mixed with sewer air, has been regarded as affording presumption that the two facts were directly connected. For example, it has been stated that in one town out of 196 invaded houses as many as 89 or 45 per cent. had defective drains; and that, in another town, out of 548 houses invaded with typhoid fever, 151 or over 29 per cent. exhibited drain defects, and so on. It is obvious, however, that even such frequent association of disease and drain defects does not afford any presumption of causal relationship between the two, unless it can at least be shown that the existence of drain defects is very much more common in houses invaded by disease than it is in houses not invaded by disease.

Investigation in Leeds.

107. It has been the practice, for some years, of Dr. Spottiswoode Cameron, the Medical officer of Health of Leeds, to cause systematic examinations to be made of drains of houses in the course of house to house inspections, in addition to the more common examination of drains on the occurrence of infectious disease, and the results of all these drain examinations, whether in connection with disease or with house to house inspections, have been recorded in the registers of the Public Health Department. The examination, in both cases, is directed to ascertain, by means of a smell test, whether air from the drain can escape into or near the dwelling, and the procedure carried out is, in both cases, exactly the same, except that, if in a house invaded by infectious disease, the test is negative, it is repeated.

Dr. Turton, while acting as assistant to Dr. Cameron, summarised these data in a very interesting study, with a view to ascertain the relative frequency of drain defects in houses invaded by disease and in houses not invaded by disease.* Having selected typhoid fever and diphtheria as the diseases which have been most frequently supposed to be associated with drain defects, he brought under review the results of drain examinations of as many as 5,342 houses invaded by these diseases, as well as those of 2,275 houses not invaded by disease, during a period of three years (1899-1901). The table below, which summarises the results of his investigation, shows that the proportions of defective drains in houses invaded by typhoid fever, or diphtheria, and in houses not invaded by disease, were 27·94, 27·88, and 27·30 per cent. respectively, or practically the same in all three classes of houses.

	No. of Houses examined.	Drains Defective.	Drains Not Defective.
GROUP I. House-to-house Inspection	2,275	621 27·30 %	1,654 72·70 %
GROUP II. Houses invaded by Typhoid Fever	1,428	399 27·94 %	1,029 72·06 %
GROUP III. Houses invaded by Diphtheria	3,914	1,092 27·88 %	2,822 72·12 %
Total	7,617	2,112 27·73 %	5,505 72·27 %

108. In this inquiry Dr. Turton was careful to exclude certain possible fallacies. Thus, the dwellings brought under review were situated in 11 different wards of Leeds, so that no particular locality with peculiar sanitary and social conditions was picked out. This served the further useful purpose of excluding the personal element in the examination of the drains, for the facts he investigated had been recorded by 15 different inspecting officers. Furthermore, the class of house examined "house to house" and for epidemic disease, respectively, was similar. In Leeds a large proportion of the dwellings are back-to-back houses, and the proportion of

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* A Dissertation on Defective House Drainage, and an Enquiry into its Influence on the Etiology of Typhoid Fever and Diphtheria"—by Edward Turton, M.D., B.Sc., Ch.B. (Vict.).

such houses among those examined "house to house" was 74 per cent., while among those examined for zymotic disease it was about 73 per cent.

109. The significance of the results, obtained in this investigation, is increased by the fact that, in Leeds, the intercepting trap is very uncommon, so that in most of the houses in question the drains were in direct aërial connection with the sewer. In 37·4 per cent. of the houses this direct connection with the sewer extended to all the drain pipes, but in 62·6 per cent. of the houses, some of the pipes (sink wastes) were disconnected from the sewer. Dr. Turton found that, although in the case of houses with partially intercepted drains, the proportion of defective drains in houses with disease was somewhat greater than in houses without disease, this proportion was practically identical in the case of houses with drains wholly in direct connection with the sewer. As Dr. Turton pointed out, this result was the opposite of what was to be expected, if sewer air had played an important part in the occurrence of disease. In the case of houses provided with water closets, which numbered 51 per cent. of the total, the soil drains were all directly connected with the sewer, and examination of Dr. Turton's records shows that the proportion of defective drains was again almost the same in these houses, whether invaded by disease or not invaded by disease. The proportion was 27 per cent. in the former and 25 per cent. in the latter.

110. A somewhat similar but smaller and less exact investigation was carried out by the State Board of Massachusetts in 1889. In a town, where epidemic diphtheria had prevailed for some time, 50 houses were selected for examination in which cases of this disease had recently occurred, and 50 houses, similar as regards location, construction and social condition of the occupants, in which no case of diphtheria had occurred for five years. The sanitary conditions of these two groups of houses are stated to have been about the same:—"Defects of plumbing, want of proper "traps, leaks in the drain pipes, and other similar defects were found about equally "in the two."*

111. Dr. Buchan, Medical Officer of Health of St. Helen's, and Dr. Hope, Medical Officer of Health of Gloucester, have been good enough, at our request, to examine the available records of their departments, to ascertain the relative proportion of drain defects in houses invaded by disease and in those not invaded by disease. In Gloucester, during four years (1905-1908), among 2,537 houses examined "house to house," drain defects were found in 548, or 23·4 per cent., while among 1,106 houses invaded by infectious disease 125, or 11·3 per cent., were found to have drain defects. In St. Helen's, during three years (1906-1908), drain defects were found in 21.4 per cent. of houses examined "house to house," in 10·1 per cent. of houses invaded by diphtheria, and in 19·3 per cent. of houses invaded by typhoid fever.

112. It is conceivable, of course, that if similar inquiries could be extended to diseases other than enteric fever and diphtheria, such as "sore throat" for example, it might be found that drain defects are more commonly associated with the presence than with the absence of such diseases. It is impracticable to carry out such an inquiry, but as "sore-throat" and certain "septic" diseases may be related with streptococcal infection, and as *streptococci* of sewage origin may, after splashing, be present in drain air, with other sewage organisms, there seems to be no inherent reason, on bacteriological grounds, for rejecting the hypothesis that such diseases may sometimes be caused by exposure to drain air. Likewise, it is conceivable that exposure to drain air in a house, in which there is a sufferer from enteric fever or other disease, the specific organism of which is contained in the dejecta, might be a factor in the causation of secondary cases among the inhabitants of the house. On the other hand, there are strong bacteriological grounds against the view that the chance of such causation can be increased by the admixture of sewer air with drain air, since, as we have already pointed out, it is an essential fact that sewage microbes are so seldom present in sewer air, even in the sewer itself, and that they are still less likely to be present in sewer air which has succeeded in passing from the sewer into the house drain, and thence, perhaps, through a layer of earth, into the dwelling.

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* Abbott, M.D., Saml. W. The distribution of diphtheria in Massachusetts—1891—Transactions of the Seventh International Congress of Hygiene and Demography, London.

Epidemiological Evidence.

113. There is a considerable amount of evidence also which indicates, in a more general way, that the passage of sewer air into house drains, owing to the absence of intercepting trap, is not productive of harm to communities.

We have already referred to Leeds. It may be mentioned that, notwithstanding the general absence of intercepting traps in this city (both on house drains and at street gulleys), its health, as judged by its rate of mortality and by its incidence of such a disease as typhoid fever, compares very favourably with that of other large towns.

In Bristol both the average general death rate and the death rate from typhoid fever are exceptionally low for so large a city. Here, in addition to the entire absence of designed sewer ventilation, a large proportion of the houses occupied by the working class are not provided with intercepting traps. Nevertheless, Dr. Davies, the Medical Officer of Health, informed us that he had been unable to establish any relationship between ill-health or any definite disease and drainage defects in any part of Bristol. The following statistics for Bristol may be quoted. During the decennia, 1881-1890, and 1891-1900, and the quinquennia 1901-1905 and 1906-1910, the average annual "all causes" death rate in Bristol was 19·3, 18·3, 15·6 and 13·1 per 1,000 respectively, as compared with 21·6, 20·2, 17·0 and 14·8 per 1,000 respectively in the principal towns of England and Wales. During the same periods the death rate from enteric fever in Bristol was 17, 11, 9 and 3 per 100,000 respectively, as compared with 26, 20, 12 and 7 in all large towns.

In Leicester again the drains of most of the houses are not intercepted from the sewer, and here also the rates of mortality are low. For the same periods as given above for Bristol the annual average death rate from all causes in Leicester was 20·6, 18·3, 14·5 and 12·8 per 1,000 respectively; that from enteric fever was 21, 18, 6 and 3 per 100,000.

In Sheffield many houses are without intercepting traps, Dr. Scurfield, the Medical Officer of Health, being of opinion that the danger of admitting sewer air into the house drain has been exaggerated. In Stockport also the majority of houses are without intercepting traps, and in this town many such traps have been removed. The Medical Officer of Health, Dr. Corbin, has been unable to find evidence that harm has resulted. Similar experience is to be found in other large towns, but of these we have no exact particulars.

East Grinstead.

114. A very striking instance of this kind is provided by East Grinstead, a small town of some 7,000 inhabitants in Sussex. Although this town is largely residential there are practically no intercepting traps at all, and no ventilation of the sewers is provided except such as can take place through the soil pipes and ventilating shafts of house drains. Dr. Wallis, who has been Medical Officer of Health of this town for many years, informed us that he has been unable to trace any ill effect on the health of East Grinstead to the system of drainage in use there, and he submitted statistical data in support of this view. These show that the annual general death rate in East Grinstead during the last twenty years has always been low, ranging from 14·2 to 8·9 per 1,000. During the four successive quinquennial periods between 1891-1910 the average annual death rates were:—13·2, 11·9, 9·7 and 9·9 per 1,000 respectively as compared with 18·7, 17·7, 16·0 and 14·6 per 1,000 respectively in England and Wales. During the same period, 31 cases of enteric fever were notified in East Grinstead, an average annual attack-rate of only 25 per 100,000 of the population. Diphtheria likewise has had a small incidence there, while the average death rate from the principal epidemic diseases, including diarrhœa, was also low, viz., 0·9 per 1,000.

It is important to note that from time to time, drain defects, similar to those found in other places, have been found in East Grinstead, and that the measures taken in regard to defects in house drains are similar to those taken in other towns. Nothing exceptional in this connection has been done.

Germany.

115. Mr. Durham brought to our notice the experience of certain towns in Germany in this connection. In Germany, as we have already mentioned, it is unusual to provide an intercepting trap on the house drain, and in many towns the trap is actually prohibited. Mr. Durham informed us that the omission of the trap

originated with an Englishman, the late Mr. Lindley, the designer of several sewerage systems on the continent. Mr. Lindley was opposed to the principle of the intercepting trap, holding that the house drainage systems should be regarded as an integral part of the sewer system, and this, we understand, is the accepted view in Germany.

Mr. Durham has himself had large experience in continental drainage work, and he informed us that he has never heard of any complaint being formulated in Germany, as a result of the absence of the intercepting trap, although, owing to the severe winters there, the house drainage pipes, which are above ground, are placed inside the house. Indeed, he stated that the only important German town which, in his experience, insisted on the provision of an intercepting trap, viz., Cologne, had since 1896 prohibited its use, and that, in that town, many existing traps had since been removed.

Mr. Durham gave us much interesting information as to German methods in the drainage of houses, the most important of which was in regard to the German method of construction of sink and bath waste pipes. These do not discharge into the open air as is usual in this country, but into a common waste pipe similar to, but of smaller diameter than a soil pipe, and ventilated like a soil pipe. These pipes, like the soil pipes, are placed inside the house, and are constructed of iron. In Germany underground pipes are usually constructed of cast-iron with lead joints, and if stoneware pipes are used the joints are made with asphalte and not with cement.

116. The vital statistics of certain German towns, which have been sewered in recent years, were submitted by Mr. Durham as showing that the omission of the intercepting trap has not done harm. Without laying undue stress on these statistics, it is suggested that, if the admission of sewer air into house drains is likely to be a factor in the dissemination of disease, it might be expected that the lowering of the general death rate and that from typhoid fever, which usually follows systematic drainage of a town, would be absent or less marked in those towns which have not required the intercepting trap. There is no evidence of this, however, in the available statistics. The improvement of health after systematic drainage seems to have been quite as striking in these towns as in many English towns under like circumstances, both in Cologne, which formerly required the trap, and in the other German towns which did not. The following figures are taken from the Annual Summary of the Registrar General of England and Wales.*

In Berlin the general death rate has fallen from 26·5 per 1,000 in the quinquennium 1881-1885 to 15·5 per 1,000 in 1906-1910, or by 41½ per cent. ; in Hamburg from 25·2 to 14·8 per 1,000 in the same periods ; in Dresden from 25·0 to 14·7 ; in Breslau from 31·3 to 21·2 ; in Munich from 30·4 to 17·4 ; and in Frankfort from 19·7 to 13·8. In Cologne† the death rate fell from 26·6 in 1881-1885 to 17·5 per 1,000 in 1906-1910, or 34 per cent.

The statistics as regards mortality from enteric fever are similar. For the same quinquennia, 1881-1885 and 1906-1910, mortality from this disease in Berlin amounted to 23 and 4 per 100,000 respectively ; in Hamburg 28 and 4 ; in Dresden 18 and 4 ; in Breslau 29 and 5 ; in Munich 17 and 2 ; and in Frankfort 12 and 2. In Cologne† the mortality amounted to 25 and 3 respectively.

America.

117. In the course of our inquiry we have also received interesting information from America. The tendency there appears to be to abandon the intercepting trap, and, although we have no statistical information, we understand that where it has been given up or its provision is not enforced no harm has resulted.

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* The figures for Frankfort-on-Main and Cologne have been supplied to us by Dr. Simon and Herr Karl Zimmermann respectively of the Municipal Statistical Offices of these towns.

† In 1888 Cologne was enlarged by the incorporation of many outlying places. The death rate from all causes in the quinquennium 1891-95 was 24·4 per 1,000, and that from enteric fever, 12 per 100,000.

PART VII.

VENTILATION OF SEWERS.

118. So far we have dealt with the question of the intercepting trap without reference to the ventilation of sewers. We have done so intentionally, because as we pointed out at the outset, the objection, adduced by opponents of the trap, that it prevents the ventilation of the sewer by the house drain, is regarded by those who favour the trap as the main reason for retaining it. But now that we have investigated the advantages and disadvantages of the trap, apart from their bearing on sewer ventilation, we may briefly consider the latter point of view.

The opposing contentions are, on the one hand, that the intercepting trap makes the ventilation of sewers difficult and costly, and that, without the trap, the ventilation of sewers may be effected, through the soil pipes of house drains, safely, and without nuisance; on the other hand, that it is the business of the responsible public authority to make independent provision for the ventilation of public sewers, and that it is improper to make use of house drains for this purpose, not only because they are private property, but also because, even if such a proceeding is unlikely to cause illness, it may be offensive from the escape of sewer air near windows and chimneys.

As to the latter objection, we have already pointed out (pars. 69 and 114) that the experience of East Grinstead and other places shows that the result of using private house drains for ventilating sewers is, usually, not to increase, but to lessen the nuisance that may arise from the escape of sewer air. There can be no doubt, too, for it has been repeatedly proved, that, so far as nuisance is concerned, the escape of sewer air at a height is much to be preferred to its escape at the ground level.

Importance of Sewer Ventilation Exaggerated.

119. On the other hand, it is probable that, in the controversy that has taken place upon the intercepting trap, too much importance has been attached to the question of sewer ventilation, for there is a considerable amount of evidence which indicates that the necessity for ventilation of sewers has been exaggerated.

The ventilation of sewers—and by this term we mean the free and systematic ventilation of sewers—is usually regarded as necessary for two main reasons, viz.: (1) to prevent the forcing of drain traps inside and about houses by pressure of air from the sewer, and (2) to enable sewer men to do their work in safety.

As regards the prevention of pressure on house traps, we have already detailed experiments which show that, even in Bristol, in spite of the absence of any designed sewer ventilation, pressure on the intercepting trap did not arise, when the sewer was surcharged, until the opening of the sewer connection in the sewer was submerged; and that, therefore, if the intercepting trap is absent, pressure on the house traps, such as that of a water closet, is, likewise, not liable to occur until the sewer connection is submerged.

As to the pressure on the intercepting trap which, in the Bristol experiments, arose after the submersion of the sewer connection, we have also pointed out that not only can this pressure not be avoided by any system of sewer ventilation, short of the ventilation of every sewer connection, but also that similar pressure on house traps is manifestly unlikely to occur when the intercepting trap is absent, if the pipe to which house traps are connected is ventilated in the customary manner.

It appears, therefore, that, for the purpose of preventing pressure of sewer air on house traps, the necessity for the independent ventilation of sewers is not established; and that, as we have already explained, this is mainly because it is impracticable to make systems of sewers airtight.

120. Furthermore, the experience of Bristol does not suggest that a system of sewers, which is not ventilated, is attended with more risk to sewer men than a system which is freely ventilated. Sewer men in Bristol have been singularly free from accident, although it appears that, before men are admitted into a sewer, the usual precaution taken is to open several adjoining manholes about an hour beforehand, a precaution which is commonly taken in towns whose sewers are freely ventilated.

There is evidence to show, however, that, under any circumstances, great care should always be exercised, in the case of large sewers, in which men can walk, to ascertain that the interior is safe before men are admitted, and that the existence of means of free ventilation should never be regarded as a sufficient safeguard in itself. The history of accidents which have occurred shows that dangerous conditions may arise very unexpectedly in large sewers. For instance, in a case at East Ham, investigated by Dr. Haldane, where five men were suddenly overcome and drowned in a large outfall sewer, it appears that the spot at which the accident happened was regarded as quite safe, and that men had been in the habit of entering the sewer there daily for several years, without taking any special precautions. Yet, on the fatal occasion, a man entering in the usual way was observed to fall at once into the sewage, and four men who followed in succession to the rescue of their comrades were similarly overcome. Dr. Haldane's investigations showed that this disaster was caused by sulphuretted hydrogen, but the conditions which gave rise to the accumulation of this dangerous gas could not be exactly determined, although it was surmised to have been due to the combined effects of a high temperature and a shortage of public water supply, which led to unusually rapid putrefaction of sewage, both in the sewers and in the intercepting traps of house drains.

There have been somewhat similar accidents elsewhere in ventilated sewers, and Dr. Haldane is of opinion that, in some cases, the disturbance of sewage, caused by men wading in it, has led to the unexpected evolution of sulphuretted hydrogen.

A new danger has arisen of late, we understand, from the occasional discharge of petrol into sewers. This proceeding requires to be sternly repressed, not only because it may imperil the lives of sewer men, but also because of the risk of explosion. Ventilation of sewers cannot be an effectual safeguard against this danger.

In the case of sewers which are too small for men to enter, which, as a rule, include those of a smaller diameter or height than about 3 ft. 6 in., it would seem that the need for their ventilation, on account of risk to sewer men, hardly exists at all, and that the important requirement is that the manhole chambers on such sewers are safe when men have to descend into them. To ensure this it is usual to open two or more adjoining manholes, so as to induce currents of air for the time being.

121. If, therefore, the objection to the intercepting trap rested solely or mainly on its interference with sewer ventilation, we should be inclined to question the importance of such an objection.

Difficulty of Ventilating Sewers.

122. In this connection it may be mentioned that, in places where more or less elaborate means of sewer ventilation have been adopted, their efficacy in actually producing ventilation appears to be often in doubt. In Manchester,* for instance, where several methods of sewer ventilation were experimentally tested for prolonged periods, the best proved to be one in which mechanical means were employed, air being extracted from the sewers by fans and admitted at various regulated inlets. It was found, however, that the air in the sewers was not affected more than about 180 yards from the exhaust, and that the volume of air entering at the inlets was much less than the volume extracted by the fans, although the sewers under examination were made as airtight as possible, by providing every sewer connection with an intercepting trap, and by closing all known openings except the regulated air-inlets.

Again, the factors which govern the movements of air in sewers are so complicated and uncertain, that it appears to be quite impossible to foretell whether any given opening in a sewer will act as an inlet or as an outlet for air. Even when a tall shaft is erected close to an offensive street manhole, with a view of causing the manhole to act only as an air inlet, it sometimes happens that the manhole continues to act as an offensive outlet.

123. In Leicester the sewers are very freely ventilated, for not only are intercepting traps uncommon, but many independent sewer ventilating shafts are also in existence. It appears that the object of providing the latter was largely with the view that they would act as outlets for sewer air so that the ventilating shafts of house drains would act as inlets for fresh air. Mr. Mawbey, the Borough Surveyor of Leicester, has carried out numerous systematic observations on the air currents in the sewer ventilating shafts, and he has found that, although generally the velocity of the outgoing air was greater than that of the ingoing air, they acted frequently

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* Reports to the Manchester Corporation upon the examination of the air of sewers upon which systems of artificial ventilation were tested. T. de Courcy Meade—1901, and A. S. Delépine—1906.

both as air inlets and as air outlets, even within brief periods of time. Thus in 1,042 observations on 30 sewer ventilating shafts (6 in. by 4 in.), each observation lasting 15 minutes, the anemometers recorded 619 down currents and 1,002 up currents. Many shafts, therefore, acted both as air inlets and air outlets during each observation, while some never acted as outlets. Similarly with 20 shafts of larger size, in a total of 575 observations, the instruments recorded 449 down currents and 547 up currents.*

124. Moreover, it is necessary to point out that, if the ventilation of sewers and the exclusion of sewer air from house drains by intercepting traps were proved to be necessary, it would be requisite to make provision for the separate ventilation of every sewer connection, for, as the Bristol experiments showed, it is only when the aërial continuity of sewer and sewer connection is interrupted, that sewer air is likely to pass into the house drain. Such a system of ventilation would be not only costly but difficult, if not impossible, to carry out generally, for it would involve the erection of ventilating shafts on and their projection above the fronts of houses, to which, as we have already pointed out (par. 10), there is naturally great objection. If the intercepting trap is omitted, however, the ordinary house drain ventilating shaft at the back of the house serves as outlet, not only for air from the sewer itself, but also for air from the sewer connection, after its opening into the sewer has been submerged.

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* Report to the Highway and Sewerage and Sanitary Committee of the Borough of Leicester on "Sewer Ventilation," by E. G. Mawbey, M.Inst.C.E.—1899.

PART VIII.

SUMMARY AND CONCLUSIONS.

125. In the foregoing pages, we have shown that the disadvantages involved by the use of the intercepting trap are substantial and of serious practical importance, and that as the most important of the effects of these disadvantages are concealed from view, they may remain in existence, quite unknown to the householder. On the other hand, the construction of house drainage may be simplified by the omission of the intercepting trap (pars. 9 to 40).

The disadvantages of the trap may, to some extent, be obviated. Thus, the objectionable features of the fresh air-inlet may be overcome, apparently without detriment, by omitting this contrivance altogether. The only "ventilation" which appears to be required on a house drain, apart from anti-syphonage pipes, is that which should be provided by an opening at the top of each soil pipe (pars. 10 to 12).

The tendency of the intercepting trap to retain a considerable proportion (averaging, according to our experiments, from 42 to 79 per cent.) of the solid matters of the sewage passing through it at any given time, and thus to favour blocking of the trap as well as putrefaction of the sewage before it reaches the sewer, may be diminished, to a great extent, by using a trap of smaller diameter than is customary at present (pars. 13 to 17, 31 and 32).

The liability of the trap to become blocked appears, however, to be insuperable, and it is this liability which constitutes its most serious disadvantage. The accumulation of sewage in the drain produced by the block, and from which many undesirable consequences may follow, is not usually evident with ordinary use of the drain, and therefore may long remain undiscovered. This unsuspected blocking of the trap and accumulation of sewage appears to be very common, evidence of it having been found in more than 23 per cent. of 5,600 traps, which were specially examined (pars. 18 to 28).

Although the liability to blocking is inherent in any intercepting trap, its evil effects can be minimised by constructing the house drain, or at least the lower part of it, of iron pipes, and by closing, with a removable cover, the usual open channels in the inspection chamber which is provided as means of access to the trap. The object of these measures is to ensure that the effects of a block at the intercepting trap may become evident as soon as possible, and may admit of easy remedy without nuisance arising; and also to reduce to a minimum the chance of leakage from that part of the house drain which must be filled with sewage before a block at the intercepting trap can be discovered with ordinary use of the drain (pars. 33 to 38).

126. On the other hand, it seems to be established that the trap does serve as an effectual barrier to the entry of sewer air into the house drain, which is the fundamental advantage claimed for it. It is not liable to be forced and rendered useless, as has been supposed to be the case, by pressure of air from the sewer. This, it would appear, is chiefly because sewers are not air tight, under practical conditions, and therefore air in a sewer finds easier outlets than the water seal of the trap. The pressure which is liable to force the intercepting trap is limited to that which arises in the sewer connection after its opening into the sewer has been submerged, that is to say, after the aërial continuity of sewer and sewer connection has been destroyed. Likewise, the volume of air which can be forced through the trap is limited to that contained in the sewer connection (pars. 41 to 50).

Furthermore, when an intercepting trap has been forced in this way, the water seal is not destroyed. When the pressure is relieved, the trap will remain sealed, though, it may be, to a less depth than formerly, and, therefore, air is not liable to pass continuously through a trap, once it has been forced (par. 48).

127. In the absence of the intercepting trap the traps on even an unventilated house drain are, similarly, not liable to be forced by pressure from the sewer; and they are not liable to be forced, even after the sewer connection has been submerged, provided the house drain is furnished with a proper ventilating shaft (pars. 53 and 54).

If owing to exceptional circumstances, such as the absence, or the blocking, of the ventilating shaft of the house drain, pressure is exerted against the traps on the drain, only one trap is liable to be forced, namely, that which has the weakest water seal. Air from a drain is not liable, therefore, to pass into a dwelling through a trap, unless it so happens that the weakest trap of all the traps on the drain belongs to one of the sanitary fittings inside the house. In this connection, it needs to be borne in mind again that the water seal of an efficient trap, which has been forced, is not destroyed. At the same time provision should be made, as indicated in our report, against the tendency of ventilating shafts to become blocked by rust (pars. 48, 55 to 57).

128. The main sources from which air from the sewer may gain entry into a house, in the absence of an intercepting trap, are defects in the drain and the open top of the soil pipe or ventilating shaft; such entry being in either case merely passive, or actively induced by aspiration, in consequence of differences of temperature (par. 51).

The entry of sewer air into the dwelling through defects in the drain may be practically excluded if the house drain is constructed of iron pipes. An iron drain can be made absolutely air tight without serious difficulty, and usually remains air tight, contrary to what is feasible in the case of stoneware drains. It is probable, therefore, that the entry of sewer or drain air into a house can be limited in practice to what may come from the ventilating shafts outside (pars. 59 and 60).

129. Assuming that, in a given case, air from a drain, or from a ventilating shaft, can enter a house, the essential question is whether there is any difference, so far as the inhabitants are concerned, between the entry of sewer air *plus* drain air, and the entry of drain air alone. For if, in the absence of an intercepting trap, sewer air together with drain air can escape from a given drain or a ventilating shaft into a dwelling, it is equally possible, assuming the presence of an intercepting trap, that drain air alone will escape into the dwelling (pars. 51 to 61).

130. We have collected and carefully considered the chemical evidence, the bacteriological evidence, the results of recent and exact experiments on animals, as well as the general and epidemiological evidence, in their bearing upon the existence of definite risk to health as a consequence of the access of sewer air into the house drain in the absence of the intercepting trap (Parts III., IV., V., VI.).

131. It is difficult to summarise this evidence, and it must, therefore, be studied in the body of our report. Briefly, however, it may be said that the chemical evidence shows that the most frequent characteristic of sewer air is the presence of smell. This smell is due to the presence of certain volatile substances, given off from sewage, in such minute quantities as to be harmless in themselves, apart from smell, or, possibly, to effluvia from moulds which may be attached to the walls of sewers. It is established that the smell of sewer air is only very exceptionally due to sulphuretted hydrogen, contrary to what has been supposed, and that this dangerous gas is, usually, not present, even in minute traces, in the air of sewers (pars. 62 to 69).

132. The bacteriological evidence shows that micro-organisms of sewage origin are very rarely present in sewer air. On the other hand, they may be present in drain air in large numbers. This difference is the result of the splashing of sewage which occurs in drains, and which does not usually occur in sewers. The effect of any given splashing in a drain is of extremely short duration, the bacteria subsiding with great rapidity, but air currents, produced by ventilation, may, meanwhile, have conveyed these bacteria for considerable distances along the drain or into ventilating shafts of the drain. On the other hand, owing to the rarity of bacteria of sewage origin in sewer air, which has been repeatedly established, opportunity very rarely occurs for their convection, by air currents, from sewer to house drain, in the absence of the intercepting trap; indeed, direct experiments show that the possibility of such convection is so small that its practical importance in relation to danger to health is infinitesimal.

The bacteriological evidence undoubtedly indicates that the bacterial danger of sewer air is incomparably less than the bacterial danger of drain air; and that, therefore, the entry of sewer air, into a house, is of correspondingly smaller importance, bacterially, than the entry of drain air (pars. 70 to 97).

133. The foregoing evidence is confirmed by experiments on animals which show that while animals may be adversely affected by exposure to the concentrated effects of putrefying excrementitious substances, they are not affected, either in their growth and nutrition, or in their susceptibility to disease, by exposure to sewer air (pars. 104 and 105).

134. It is also confirmed by the general and epidemiological evidence, which is to the effect that human beings deliberately exposed to the effects of sewer air do not appear to be affected in health ; that the association of the incidence of certain specific diseases, such as enteric fever and diphtheria, with drain defects which allow of the entry of sewer air as well as of drain air into houses, is almost identically the same as the association of similar defects with the absence of disease ; and that the experience of districts without intercepting traps does not show that their absence has been harmful (pars. 98-116).

135. The necessity of the intercepting trap, on bacteriological or epidemiological grounds, has not therefore been established. It appears, in fact, that the characteristic of sewer air which is of practical importance is its smell, and that, therefore, the question, as to the necessity or otherwise of the intercepting trap, is narrowed down to the issue whether, in any given case, sewer air will be more perceptible or less perceptible to the sense of smell, with or without the trap.

Nevertheless, the question is one of serious public health importance. Human beings vary greatly in their perception of smells, and offensive and unpleasant odours affect the comfort and physical well-being, and probably the health, of the individual. It is, obviously, most important that public health authorities should make every effort to secure that both sewers and house drains are so designed and constructed, that the opportunities of their contributing smell to the atmosphere, shall be reduced in every possible way.

In ordinary cases, the smell of sewer air is less perceptible, not more perceptible, when the intercepting trap is omitted, and chiefly, it would appear, because in the absence of the trap opportunity is afforded for sewer air to escape, entirely, at a height above the ground. But there are exceptional cases, where the intercepting trap may be required, in order to prevent perceptible smell from the escape of sewer air from the tops of ventilating shafts of house drains. Sewage may be so offensive that the escape of sewer air, even at a height, is a perceptible nuisance, so much so that it may be necessary to close as many sewer ventilators as possible, whether at the ground level or at a height ; house drains may be connected with cesspools, flat or storage sewers, or with sewers which are old and foul with deposit ; houses may be built in terraces, one above the other, so that the ventilating shafts of the house drains of one terrace are at or about the level of the ground of another terrace ; and so forth.

As circumstances in this respect will vary in different localities, the question whether, in order to prevent nuisance from smell in such exceptional cases, the intercepting trap is or is not required in any locality, or part of a locality, is one which will need to be considered and determined by the local authority and their advisers, in the light of local conditions. Where, however, the trap is considered to be necessary or desirable, the measures for providing against the effects of blocking of the trap should not be neglected, namely, the closure of the open channels in the inspection chamber giving access to the trap, and the construction with iron pipes of the main portion of the house drain, unless this is remote from the house.

136. The importance of the effect which the presence of the intercepting trap has on the ventilation of sewers, on which much stress has been laid, has probably been exaggerated. The free ventilation of sewers appears to be unnecessary either for the prevention of pressure of sewer air on traps, or for the safety of sewer men, except in the case of sewers which are large enough to admit them. Even in such sewers, however, it is dangerous to rely on ventilation alone, and special precautions should always be taken. Moreover, it is exceedingly difficult to ensure that sewers are freely ventilated, even when the most elaborate measures for this purpose are adopted. On the other hand, the prevention of nuisance from smell renders it necessary that any openings which may be deemed to be requisite for the ventilation of sewers should not be at the ground level (pars. 118-124).

137. The relationship between the splashing of sewage and the temporary presence of sewage microbes in drain air, and the wafting of such microbes to considerable distances by currents of air, which has been established in the course of our inquiry, appears to be a matter of practical importance, whether the intercepting trap is present or not. The bacteriological evidence suggests that if exposure to drain air is related, as many suppose it is, to attacks of sore throat or other septic affections, the explanation may be found in the liability of drain air, unlike sewer

air, to carry in suspension large numbers of microbes of sewage origin (pars. 78 to 97, and 112). It is desirable, therefore, that the possibility of splashing should be taken into account in the construction of drains, in order that it may be reduced to a minimum. It is, likewise, important, whether the intercepting trap is present or absent, that the tops of soil pipes and of the ventilating shafts of house drains should be as remote as possible from windows, not only with a view to avoid smell, but also to minimise the chance of sewage microbes, which may be present in drain air, being wafted from them into the dwelling.

138. In concluding our report we wish again to express our sincere thanks to all those who have afforded us assistance in the course of our inquiry, either by giving evidence or by conducting experiments for us. We also wish to record our appreciation of the services rendered by our Secretary, Mr. E. Hardwick Terry, who has been most assiduous in carrying out his arduous duties, and whose technical qualifications have proved especially valuable in an inquiry of this nature.

We have the honour to remain, Sir,

Your obedient servants,

(Signed) L. W. DARRA MAIR, *Chairman.*

ALLAN A. G. MALET.

H. JOHN PEARSON.

E. HARDWICK TERRY, *Secretary.*

22*nd December*, 1911.

APPENDICES.

APPENDIX I.

LIST OF WITNESSES.

Name of Witness.	Description.
Allan, Dr. F. J., M.D.	Medical Officer of Health of Westminster.
Andrewes, Dr. F. W., M.A., M.D., F.R.C.P.	Pathologist at St. Bartholomew's Hospital, London.
Bailey, Mr. T. J., F.R.I.B.A.	Late Architect to the Education Department of the London County Council.
Barber, Mr. J. Patten, M.Inst.C.E., F.R.San.I.	Borough Engineer of Islington.
Barlow, Dr. T. W. Naylor, M.R.C.S., L.R.C.P., D.P.H.	Medical Officer of Health of Wallasey.
Best, Mr. H. Robertson, M.A., M.Inst.C.E.	Civil Engineer.
Binnie, Sir Alexander R., P.P.Inst.C.E. ...	Consulting Engineer.
Brodie, Mr. J. S., M.Inst.C.E., F.R.San.I. ...	Borough Engineer and Surveyor of Blackpool.
Bryett, Dr. L. T. Fraser, M.D., D.P.H. ...	Medical Officer of Health of Shoreditch.
Buchan, Dr. J. J., M.D., D.P.H.	Medical Officer of Health of St. Helen's, Lancashire.
Butler, Dr. W., M.D., D.P.H.	Medical Officer of Health of Willesden.
Cameron, Dr. Spottiswoode, M.D., B.Sc. ...	Medical Officer of Health of Leeds.
Carter, Mr. G. F., M.Inst.C.E.	Borough Engineer and Surveyor of Croydon.
Clarke, Mr. Max, F.R.I.B.A.	Architect.
Cooper, Mr. W. G.	Chief Sanitary Inspector of Bournemouth.
Corbin, Dr. H. E., B.Sc., D.P.H.	Medical Officer of Health of Stockport.
Davies, Dr. D. S., M.D.	Medical Officer of Health of Bristol.
Durham, Mr. F. R., A.M.Inst.C.E.	Civil Engineer.
Fitzmaurice, Mr. Maurice, C.M.G., M.A., M.Inst.C.E.	Chief Engineer to the London County Council.
Haldane, Dr. J. S., F.R.S., M.D.	Reader of Physiology, Oxford University.
Haynes, Mr. R. H., M.Inst.C.E.	Late Borough Surveyor of Newport, Mon.
Hope, Dr. W. M., D.P.H.	Medical Officer of Health of Gloucester.
Horrocks,* Major W. H., R.A.M.C. ...	Ex-Medical Officer of Health of Gibraltar.
Hurtley, Dr. W. H., D.Sc.	Lecturer on Chemistry at St. Bartholomew's Hospital.
Hustler, Mr. T. L.	Borough Engineer and Surveyor of Shoreditch.
Lacey, Mr. F. W., M.Inst.C.E., F.R.I.B.A. ...	Borough Engineer of Bournemouth.
Lynam, Mr. G. T., M.Inst.C.E.	Borough Engineer and Surveyor of Burton-upon-Trent.
Marsden, Dr. R. S., M.B., D.Sc., F.R.S.E. ...	Medical Officer of Health of Birkenhead.
Mawbey, Mr. E. G., M.Inst.C.E.	Borough Engineer of Leicester.
Moss-Flower, Mr. T. J.. A.M.Inst.C.E., F.G.S.	Civil Engineer.
Murphy, Sir Shirley, F.R.C.S.(Eng.) ...	Medical Officer of Health to the London County Council.
Neech, Dr. J. T., M.D., D.P.H.	Medical Officer of Health of Halifax.
Parsons, Dr. H. Franklin, M.D.	Ex-Assistant Medical Officer to the Local Government Board.
Pinkham, Mr. C.	Member of Willesden Urban District Council.
Putten, Mr. E. van, M.Inst.C.E., M.R.San.I.	Borough Engineer and Surveyor of Lewisham.
Read, Mr. R., A.M.Inst.C.E.	City Surveyor of Gloucester.
Renney, Dr. H., M.D., D.Hy., D.P.H. ...	Medical Officer of Health of Sunderland.
Richards, Dr. H. Meredith, M.D.	Medical Officer of Health of Croydon.
Riley, Mr. W. E., M.Inst.C.E., F.R.I.B.A. ...	Superintending Architect to the London County Council.
Riley, Mr. W.	Member of the Willesden Urban District Council.
Robson, Mr. C. E., M.Inst.C.E.	Surveyor of the Willesden Urban District Council.
Scurfield, Dr. H., M.D.	Medical Officer of Health of Sheffield.
Steele, Mr. W. J., A.M.Inst.C.E.	Borough Engineer of Newcastle.
Taylor, Mr. G. Midgley, M.Inst.C.E., F.C.S., F.R.San.I.	Consulting Engineer.
Thomson, Mr. G., M.A., A.M.Inst.C.E., F.R.S.E.	Civil Engineer.
Turton, Dr. E., M.D., B.Sc., M.R.C.P. ...	Physician to the Hull Royal Infirmary.
Wallis, Dr. P. E., L.R.C.P.	Medical Officer of Health of East Grinstead
Wike, Mr. C. F., M.Inst.C.E.	City Engineer and Surveyor of Sheffield.
Wood, Mr. Searles, F.R.I.B.A., F.R.San.I....	Architect.
Woollam, Mr. W. E., C.E., M.San.I.	Surveyor of East Grinstead.
Yabbicom, Mr. T. H., M.Inst.C.E.	City Engineer of Bristol.
Young, Mr. I., M.R.San.I., F.S.I.Assoc. ...	Chief Sanitary Inspector of Battersea.

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* Now Lieutenant-Colonel Horrocks.

APPENDIX II.

Results of Examination of Intercepting Traps in 21 Suburban Districts.

District.	Approximate Population.	Number of traps examined.	Number of traps blocked.	Percentage of blocked traps.	No. of chambers which show that there has been previous accumulation of sewage.	Percentage of chambers which show evidence of previous accumulation.	Number of raking or cleansing arm stoppers displaced.	Percentage of raking arm stoppers displaced.
1	32,000	401	11	2·7	12	3	30	7·5
2	34,000	168	6	3·6	35	20·8	7	4·2
3	14,000	252	15	6	96	38·1	19	7·5
4	13,000	27	1	3·7	No information		No information	
5	9,000	151	6	4	12	8	6	4
6	39,000	1,152	110	9·5	191	16·6	71	6·2
7	170,000	778	33	4·2	129	16·5	54	6·9
8	65,000	310	16	5·2	107	34·5	18	5·8
9	61,000	139	22	15·8	3	2·2	19	13·7
10	134,000	170	43	25·3	No information		No information	
11	65,000	50	7	14	1	2	16	32
12	56,000	254	16	6·3	17	6·7	4	1·6
13	28,000	567	30	5·3	92	16·2	49	8·6
14	39,000	147	4	2·7	17	11·6	4	2·7
15	10,000	97	4	4·1	No information		4	4·1
16	85,000	597	42	7	No information		15	2·5
17	125,000	140	14	10	18	12·9	11	7·7
18	21,000	108	26	24·1	11	10·2	7	6·5
19	137,000	270	23	8·5	27	10	3	1·1
20	289,000	302	10	3·3	162	53·6	35	11·6
21	55,000	412	6	1·5	2	0·5	3	·7
Totals -		6,492	445	6·9	932*	16·6	375†	6

* The total number of traps examined for this condition was 5,601.

† Do. do. do. 6,295.

APPENDIX III.

EXPERIMENTS AT BRISTOL

Carried out by

Mr. W. J. Steele, (then) Assistant to the City Engineer.

EXPERIMENT G made on Marsh Street Sewer, Bristol, 24th March, 1909.

This experiment was carried out in the presence of the Departmental Committee, in continuation of experiments (A and B) described by Mr. Steele in his evidence, for the purpose of ascertaining the effect on intercepting traps when the air in a sewer is displaced by the surcharging of such sewer, as may occur in a tide-locked outfall, or during a heavy rainfall in a free outfall, or by a combination of these circumstances. For the plan and section of the site of the experiments see diagram I. The results are shown in detail in the table (page 52), and graphically on diagram II.

The sewer chosen for the experiments is of brickwork, 5 ft. high by 4 ft. 6 in. in width, and is subject to tidal influence. On the date of experiment there was an exceptionally high tide, the maximum head of water against the top of the outfall into the river Avon being nearly 16 ft. The sewer outfall is provided with a tidal flap, consequently, although there was a head against the top of the outfall of nearly 16 ft., as above stated, the maximum head against the top of the sewer connection (ABC), on which the experiment was made, was much less, only 5 ft. This, however, is a very considerable head, and one which is seldom, if ever, reached in a modern sewerage system.

It will be observed from diagram II. that the maximum head in the sewer occurred at 10.45 a.m., or $1\frac{3}{4}$ hours after high water, when the tide had dropped 8 ft.; the explanation of this is, of course, that the sewer continued to fill up until the head of water in it was sufficient to cause a discharge at the outfall. During the filling of the sewer there was no rainfall, but the period was at the maximum rate of dry weather flow.

The sewer connection under consideration had two intercepting traps connected to it, one (C) named "Test Trap," and the other (E) "Private Premises Trap." The test trap was provided with glazed observation panels fitted with a scale, the zero of which was the normal water level in the trap. The water seal was $3\frac{2}{10}$ths in. The private premises trap was a stock pattern and had a water seal of about 2 in.; it was fixed in an inspection chamber immediately inside the building line of the property.

The sewer connection, although carefully laid by the Corporation workmen, could not have been air-tight, for neither intercepting trap was forced until there was a head against the sewer connection of about 3 ft. In experiments C and D (page 53), which were made on an experimental sewer connection proved to be air-tight, it was found that air was forced through the water in a trap on it, when the head against the sewer connection just exceeded that in the trap.

The water in the traps in experiment G was not affected until the sewer connection was submerged. When this occurred the water in both traps began to oscillate immediately, and such oscillation caused the water seal to be reduced by 1/10th in. in both cases. Nothing further happened, however, in the traps for 80 minutes, when the water began to rise in the inlet leg of both traps, at which time the head against the sewer connection had increased to about 2 ft. 9 in. As the head against the sewer connection increased, the water in the inlet leg of both traps continued to rise until at 10 a.m., or 95 minutes after the submersion of the sewer connection, when there was a head of about 3 ft. against it, the level of water in the test trap was 2 in. above zero, and in the private premises trap, $1\frac{9}{10}$ths. in. above zero. At this stage puffs of air passed from the sewer connection through the water in the last-named trap, but none passed through the test trap. This condition continued until 10.45 a.m., at which time the maximum head of 5 ft. against the sewer connection was reached. The level of the sewage then commenced to fall. The water in the inlet leg of both traps also fell, until it was $1\frac{6}{10}$ths in. below zero in the private premises trap, or at the bottom of the sill of trap, and $1\frac{5}{10}$ths in. below zero in the test trap. Puffs of air now passed through the water in the private premises trap back into the sewer connection. This condition continued until the sewage fell to about 2 ft. above the sewer connection, when the water in both traps came to an even level, showing a loss of water in each trap of 6/10ths in., thus leaving a seal of $2\frac{6}{10}$ths in. in test trap and $1\frac{4}{10}$ths in. in the private premises trap. (*See table and diagram.*)

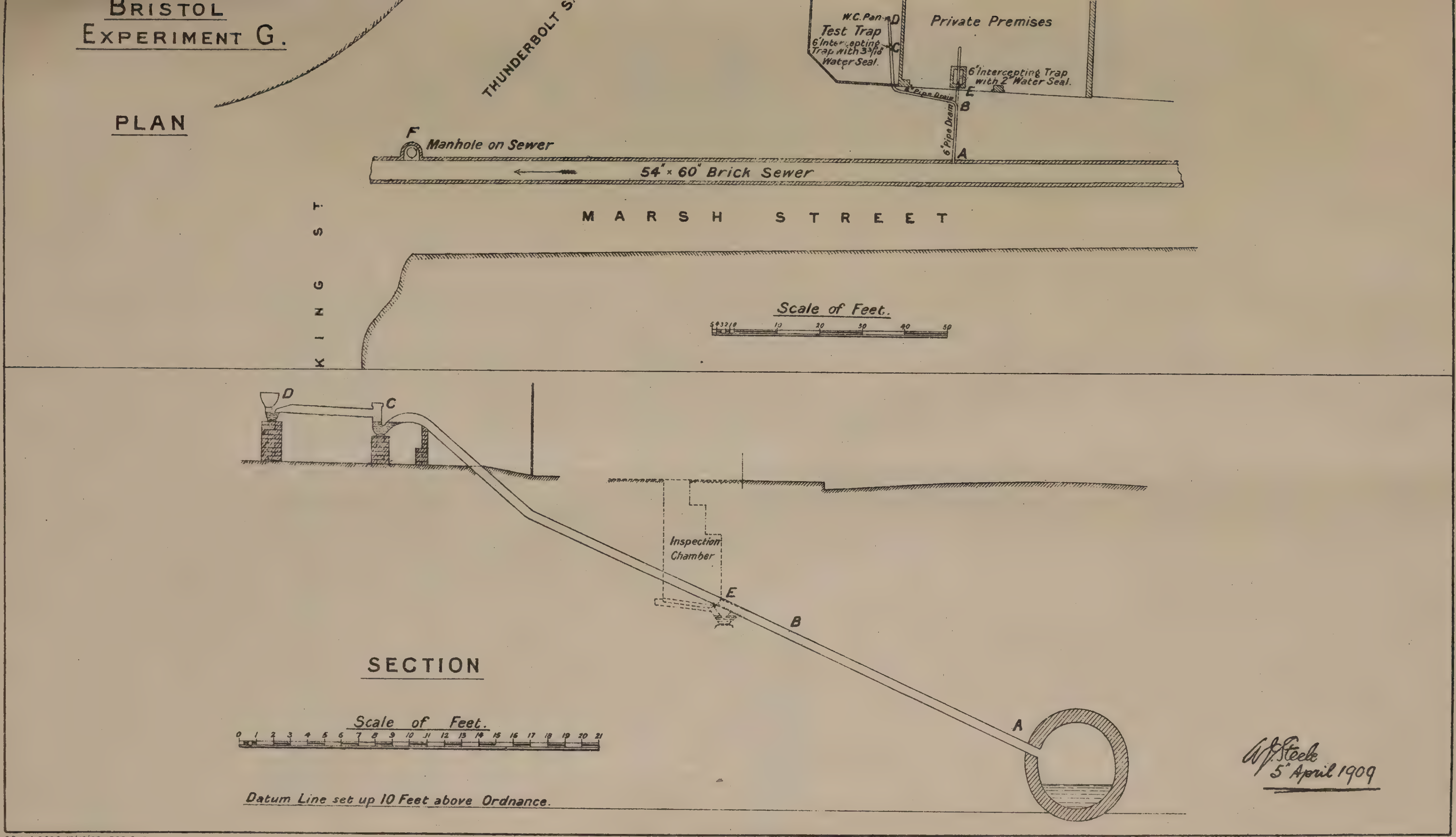
In conjunction with experiment G, an experiment H was concurrently made on a trap fixed to the same sewer at a paint 1,600 yards distant from, and 59 ft. above that in experiment G. No perceptible movement occurred in this trap until just after the ponded sewage began to recede, when a loss of 1/20th in. of water was registered.

EXPERIMENT G.

Time.	Level of Water in River, above Ord. Dat., in feet.	Level of Water in Sewer at Man-hole (F) above Ord. Dat., in feet.	Head of Water on top of Sewer connection, in feet.	Level of Water in Inlet leg of Test Trap relative to zero, in inches.		Level of Water in Outlet leg of Test Trap, relative to zero, in inches.		Level of Water in Inlet leg of Intercepting Trap in private premises, relative to zero, in inches.		REMARKS.
A.M.				Above.	Below.	Above.	Below.	Above.	Below.	
8.00	...	...	...	0	0	0	0	0	0	
8.15	...	13.39	...	0	0	0	0	0	0	
8.25	...	...	...	...	...	...	...	...	...	Water in both traps oscillating.
8.30	...	...	...	...	1/10	...	1/10	...	1/10	Loss of water apparently due to oscillation.
9.00	26.82	15.67	2.02	...	1/10	...	1/10	...	1/10	High water.
9.30	...	16.11	2.46	...	1/10	...	1/10	...	1/10	
9.45	...	...	...	1/10	...	...	1/10	1/10	...	
9.50	...	...	...	8/10	...	...	8/10	1	...	Movement of water in both traps commenced.
9.55	...	...	...	$1\frac{2}{10}$	...	...	$1\frac{2}{10}$	$1\frac{2}{10}$	...	
10.00	...	17.15	3.50	2	...	...	$1\frac{4}{10}$	$1\frac{9}{10}$	...	Water oscillating in test trap. Air escaping in puffs from sewer connection, through water in private premises trap.
10.5	...	...	...	$2\frac{1}{10}$	...	...	$1\frac{5}{10}$	$1\frac{9}{10}$	...	Ditto ditto.
10.10	...	...	...	2	...	...	$1\frac{5}{10}$	$1\frac{9}{10}$	...	Ditto ditto.
10.20	...	17.98	4.33	2	...	...	$1\frac{5}{10}$	$1\frac{9}{10}$	...	Ditto ditto.
10.30	...	18.48	4.83	2	...	...	$1\frac{5}{10}$	$1\frac{9}{10}$	...	Ditto ditto.
10.40	...	...	...	8/10	...	0	0	...	...	A flush was made in the test trap and caused the water of the intercepting trap in private premises to oscillate violently during the flush, with continuous and large air bubbles. After the flush, water in test trap stood at levels given.
10.45	...	18.77	5.12	...	...	...	...	...	...	
10.50	...	18.69	5.04	0	0	0	0	...	1	Water in sewer receding. Air returning to sewer connection through water in private premises trap.
10.55	...	...	...	...	1	0	0	...	$1\frac{3}{10}$	Water in test trap oscillating,
11.00	...	18.06	4.41	...	$1\frac{5}{10}$	0	0	...	$1\frac{3}{10}$	
11.10	...	17.53	3.88	...	...	...	...	...	...	
11.20	...	16.73	3.08	...	$1\frac{5}{10}$	...	...	...	$1\frac{6}{10}$	
11.25	...	15.81	2.16	...	...	...	...	0	0	Water began to run into private premises trap, owing to a slight shower of rain.
11.30	...	...	...	...	6/10	...	6/10	...	6/10	Water in test trap returned to an even level, showing a loss of water.

DIAGRAM I.

BRISTOL
EXPERIMENT G.



W. J. Steele
5th April 1909

934. L 3596. 10/12/08 1500.8.12.

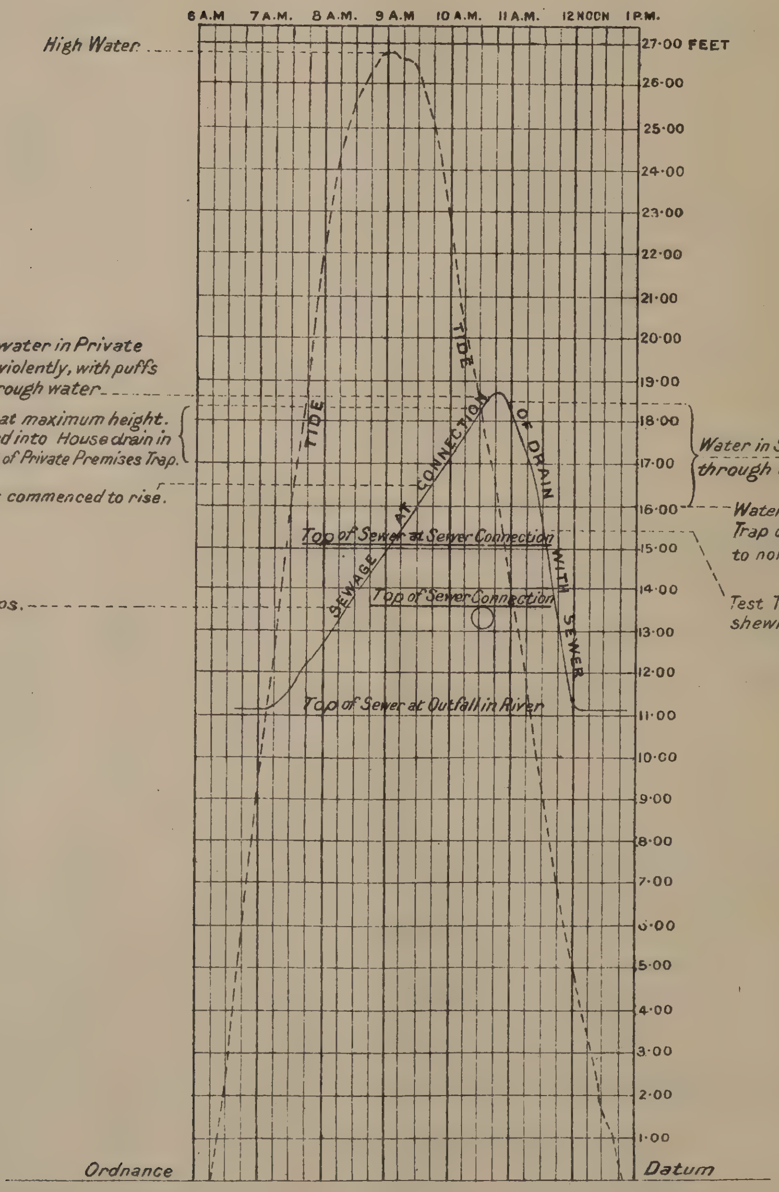
Malby & Sons, Lith

DIAGRAM II

APPENDIX III *(Continued)*

EXPERIMENT G.

TIDAL CURVE & SEWAGE CURVE IN MARSH STREET SEWER ON MARCH 24TH (A.M. TIDE) 1909.



Test Trap flushed, causing water in Private Premises Trap to oscillate violently, with puffs of air continuously escaping through water

Water in inlet leg of both Traps at maximum height. During this period, air escaped into House drain in puffs, through water in inlet leg of Private Premises Trap.

Water in inlet leg of both Traps commenced to rise.

Water oscillating in both Traps.

Water in Sewer receding. Air drawn into Sewer c
through water in Private Premises Trap

Water commenced to enter Private Premise
Trap owing to slight shower of rain filling it
to normal level.

Test Trap at same level both legs.
shewing a loss of 6/10" of Water

Test Trap – Water Seal 32/10 Inches
Private Premises Trap ·· D° 16/10 D°

W. J. Steele
5' April 1909

934. L 3030. 19/12/08. 500. 8.12.

Malby & Sons. Lith

EXPERIMENTS C, D, and E.

Experiment C.—A drain 6 in. in diameter and 21 ft. in length, with a fall of 15 in., was built up to represent a sewer connection, and the lower end was connected to a 9-in. stoneware pipe to represent a sewer. The upper end of the sewer terminated in a vertical pipe, so that a head of water might be created against the sewer connection, and the lower end was closed with a rubber-edged stopper.

The upper end of the sewer connection terminated in an intercepting trap fitted with glass observation panels; the water seal in the trap was 32/10ths in. The whole was proved to be airtight by water test.

Water was poured into the sewer until air escaped from the surface of the water in the inlet leg of the intercepting trap, clearly showing that the rising water in the sewer had forced air through the water seal. When this happened, the head of water against the sewer connection was 8 in. The water in the inlet leg of trap was 44/10ths in. above zero, and 33/10ths in. below zero in the outlet leg; the total head in the trap, therefore, was 77/10ths in. More water was poured into the sewer, and air continued to escape from the trap, but no alteration took place in the level of water in the latter.

The water in the sewer was then allowed to discharge, when the water in the inlet leg of the trap gradually descended until it was 32/10ths in. below zero, or at the level of the bend at the bottom of the trap. In the outlet leg of the trap the water was at zero. At this point the water in the outlet leg was violently agitated, and air bubbles were clearly observed passing through it into the sewer connection. When the opening of the sewer connection into the sewer was clear, the water in the trap returned to the same level in both legs, 18/10ths in. below zero, thus leaving a seal of 14/10ths in.

Experiment D.—Experiment C was repeated with a sewer connection 42 ft. in length instead of 21 ft., and a 12-in. pipe sewer instead of a 9-in. pipe. Water was poured into the sewer until air escaped from the surface of the water in the inlet leg of the trap. When this happened, the head of water against the sewer connection was 81/10ths in. The water in the inlet leg of trap was 44/10ths in. above zero, and 32/10ths in. below zero in outlet leg; the total head in trap, therefore, was 76/10ths in.

It will be seen that although the original volume of air between the sewer and the trap was about twice that in experiment C, practically the same head forced air through the water seal in the trap.

Experiment E.—In order to illustrate further the effect of pressure on traps, the sewer connection used in experiment C was fitted with three traps, No. 1 being the test intercepting trap, No. 2 a stoneware street gully, No. 3 a stock intercepting trap.

No. 1 had a water seal of 32/10ths in.
No. 2 ,, ,, 87/10ths in.
No. 3 ,, ,, 20/10ths in.

Water was poured into the sewer until air escaped from the surface of the water in the inlet leg of trap No. 3. The head of water against the sewer connection when this happened was 66/10ths in.

Water was continuously poured into the sewer until there was a head against the sewer connection of 104/10ths in., but although air was repeatedly forced through No. 3 trap, none was forced through either of the other traps.

On allowing the water in the sewer to discharge, the water in all three traps slowly descended, and air passed through No. 3 trap into the sewer connection, but in the other two traps there was only a slight oscillation. When the sewer connection was free, the water in all traps returned to the same level in both legs, leaving a water seal in—

No. 1 trap of 24/10ths in.
No. 2 ,, 71/10ths in.
No. 3 ,, 5/10ths in.

The results of this experiment serve to show that when an airtight drain is surcharged to such an extent as to exceed the head of water in the weakest trap, the displaced air is forced through such trap only; when the water in the surcharged sewer recedes, sufficient water is left even in this trap to form a seal.

EXPERIMENTS K—On the drains of two adjoining houses in Redland Green Road, Bristol.

The object of these experiments was to ascertain the effect on drain traps of the passage of sewage through the drain (1) when there was no direct communication between it and the atmosphere, that is, when both the air inlet and the ventilating shaft of the drain were closed; (2) when either the ventilating shaft or fresh air inlet alone was open; and (3) when both the ventilating shaft and air inlet were open. Details of the results are given in the following four tables.

The tests were carried out on two adjoining semi-detached villa houses in Redland Green Road, Bristol, the drains of one (house Y) having an intercepting trap, while in the other (house X) the trap had been specially removed. The arrangement of the drains in these two houses was practically the same, but in house Y the gradient was 1 in 17, while in house X it was 1 in 10. The main house drain in each case was 6 in. and the branches 4 in. in diameter. (See diagram III)

The fresh air inlet in each case was at the back of the house, at the head of the drain, and raised some 7 ft. above the ground. The mica flap was removed for the purpose of the experiments, so that the pipe could act as an air outlet. Close to the air inlet the connection from the ground-floor water-closet joined the drain, and some distance (48 ft.) further down, the drain was connected with a branch drain from the soil pipe of the water-closet on the first floor. This soil pipe was carried up above the roof and was the ventilating shaft. Between these two water-closet connections on the drain there were two other connections with surface gulley traps, one for the sink waste from the scullery, the other for the wastes from a bath and lavatory on the first floor. In the forecourt of house Y (with an intercepting trap) there was a roof-water gulley trap, which was connected with the main drain in the inspection chamber, near the front boundary fence, in which the intercepting trap was fixed. In house X this branch had been disconnected when the intercepting trap was removed.

The depths of the water seals of the various traps on the drains were carefully measured before the experiments, and are given in the tables. A record of the movements of water in these traps was obtained by means of a floating indicator, fixed in each trap, with a scale graduated to tenths of an inch.

Test No. 1.—*Both soil pipe ventilating shaft and air inlet closed.*—In this experiment ordinary flushing of either of the water-closets, or of both simultaneously, produced slight oscillations in the water of the other traps in the house Y (with an intercepting trap), but practically none in house X (without an intercepting trap). When the drain was running as full as it probably ever would—*i.e.*, bath and sink wastes discharging simultaneously with a flush from a water-closet, in both houses the water oscillated in the traps into which no discharge was taking place, but at the end of the action the only traps which had lost water were the two water-closet traps in both houses and also in the roof-water gulley in the house Y. The loss of water was very small, not more than 1/10th or 2/10ths of an inch.

When, however, water was thrown rapidly from a pail down the first-floor water-closet, such as might occur when this fitting is used as a housemaid's sink, the water-closet trap was found to be almost unsealed. This occurred in both houses alike and must have been due to syphonage. In house Y, air was also forced through the water in the gulley trap receiving the bath-waste, but this was an exceptionally weak trap, the seal being only 4/10ths in.

Test No. 2.—*Soil pipe ventilating shaft open and air inlet closed.*—In house X (without an intercepting trap), the most severe of the tests—namely, throwing water from a pail down a water-closet—produced practically no effect on the traps either of the water-closet itself or elsewhere in the drain. In house Y (with an intercepting trap) this experiment likewise caused little or no effect, except some oscillation of water in the traps, when it was made in the first-floor water-closet, connected with the open soil pipe. When, however, the experiment was made with the ground-floor water-closet, connected near the closed air inlet, the trap was partially syphoned.

Test No. 3.—*Soil pipe ventilating shaft closed and air inlet open.*—Conversely, in this case, throwing water from a pail down the first-floor water-closet, connected with the closed ventilating shaft, resulted in syphonage of the water-closet trap in both houses. Similar test on the ground-floor water-closet, connected near the open-air inlet, produced practically no effect on the traps in either house.

Test No. 4.—*Both ventilating shaft and air inlet open.*—Water thrown down the ground-floor water-closet caused slight partial syphonage of the water-closet trap, and some oscillation of water in other traps, in the house Y, with intercepting trap. No observation was made in the other house (X).

These experiments show that, even when both ventilating shaft and air inlet are closed, the traps are not affected by the passage of sewage along the drain, except when a pail of water is thrown more or less violently down a water-closet and causes syphonage. Such an action is clearly within the limits of ordinary use of the drain, so that it is evident that direct communication between the atmosphere and the drain is necessary, whether the drain has an intercepting trap or not.

It will be observed that in test No. 4 (both ventilating shaft and air inlet open), when water was thrown down the ground-floor water-closet, in house Y (with intercepting trap), not only did that trap lose 6/10ths in. of water, but the first-floor water-closet also lost 1/10th in., whereas when this action was carried out in test No. 3 (soil pipe ventilating shaft closed and air inlet open), the water-closet trap did not lose any water. There was therefore more disturbance of the trap, when both ventilating shaft and air inlet were open than there was when one was closed. The explanation may be that in No. 4 the air displaced by the water thrown down the ground-floor closet escaped through the first-floor ventilating shaft and caused a sufficient vacuum behind the trap to remove some of its water; but in No. 3, there being no means for the escape of the displaced air, the ventilating shaft being closed, the water in the intercepting trap holding it back, a vacuum was prevented. None of the experiments showed the necessity of the air inlet as such.

On the other hand, the results of tests No. 2 and No. 3 show that when water is thrown down a water-closet the trap may be syphoned, if the communication of its soil pipe with the atmosphere is closed, even if there is a ventilating opening elsewhere on the drain. This syphonage would not be of importance if the water-closet were flushed immediately after such use, but, of course, such flushing cannot be relied upon.

It appears, therefore, that the direct communication which it is necessary to provide between drain and atmosphere should be situated at the water-closet connection, by carrying up such soil pipe as a ventilating shaft, and that if there is only one water-closet—as, for example, in a cottage—this is all the ventilation of the drain that is required. If there is more than one water-closet connection with the drain, it would appear that each water-closet connection or soil pipe should be ventilated, and especially if there is an intercepting trap. It needs to be remembered, however, that when there is a first-floor water-closet, it is probably the only one used for pouring down pails of water—*i.e.*, as a housemaid's sink. Therefore, if the soil pipe of this water-closet is ventilated, it may not be necessary to provide also a ventilating-shaft at the ground-floor water-closet, although clearly it would be an additional safeguard.

Briefly, these experiments show that the essential ventilating pipes on a drain are those which will prevent syphonage of traps when the drain is used. The necessity for providing for the passage of currents of air through the drain has not been proved.

EXPERIMENTS K.

Results of Tests carried out on the Drains of two adjoining Houses in Redland Green Road, Bristol.

March, 1909.

Description of Test.	Action.	House X, without Intercepting Trap. Movement of Water in Minor Traps.					House Y, with Intercepting Trap, $2\frac{1}{4}$-in. Seal. Movement of Water in Minor Traps.				
		W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor. Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 16/10 ins.	Sink Waste Gully. Normal Water Seal 10/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 15/10 ins.	W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 4/10 ins.	Sink Waste Gully. Normal Water Seal 19/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 16/10 ins.
No. 1. Vent Shaft and "Fresh air inlet" closed.	W.C. first floor flushed.	At normal level at end of action.	Slight oscillation.	No movement.	No movement.	The drain from this gully was disconnected, so as to permit of the insertion of a straight pipe in place of an Intercepting Trap, consequently no observation was made.	At normal level, at end of action.	Slight oscillation. At normal level at end of action.	Rose 1/10 in. and returned to normal level.	Rose 1/10 in. and returned to normal level.	Rose 1/10 in. and returned to normal level.
	W.C. ground floor flushed	No movement.	At normal level at end of action.	Ditto.	Ditto.		No movement.	At normal level at end of action.	Ditto.	Ditto.	Ditto.
	Both W.C's. simultaneously flushed.	At normal level at end of action.	Ditto.	Very slight oscillation.	Ditto.		At normal level: at end of action.	Ditto.	Ditto.	Rose 2/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.
	Bath emptied, sink waste continuously discharging, and W.C. first floor flushed.	1/10 in. below normal level at end of action.	Slight oscillation, 1/10 in. below normal level at end of action.	At normal level at end of action.	At normal level at end of action.		At end of action oscillated continuously until bath ceased discharging when it became stationary at 1/10 in. below normal level.	Oscillated between 1/10 in. above and 2/10 in. below, normal level. At end of action 1/10 in. below normal level.	At normal level at end of action.	At normal level at end of action.	Rose 3/10 in. and returned to 1/10 in. below normal level.
	Bath emptied, sink waste continuously discharging, and W.C. ground floor flushed.	2/10 in. below normal level at end of action.	At normal level at end of action.	Ditto.	Ditto.		Rose 5/10 in. and returned to 2/10 in. below normal level.	At end of action oscillated between 2/10 in. above and 2/10 in. below normal level, and finally became stationary at 1/10 in. below normal level.	Ditto.	Ditto.	Fell 1/10 in. below normal level.
	Water thrown from bucket down W.C. first floor.	Water fell below bridge of trap. At end of action 16/10 ins. below normal level, *i.e.*, trap only just sealed.	No movement.	No movement.	No movement.		Water fell below bridge of trap. At end of action 16/10 ins. below normal level, *i.e.*, trap only just sealed.	Rose 5/10 in. and returned to normal level.	Rose 3/10 in. when small quantity of air was forced through water into atmosphere. At end of action 1/20 in. below normal level.	Rose 4/10 in. and returned to normal level.	Rose 6/10 in. and returned to normal level.
	Water thrown from bucket down W.C. ground floor.	Not observed.	Not observed.	Not observed.	Not observed.		Rose 3/10 in. and returned to 1/10 in. below normal level.	Water fell below bridge of trap. At end of action 9/10 in. below normal level, *i.e.*, trap was sealed.	Rose 3/10 in. and returned to normal level.	Oscillated between 2/10 in. above and 2/10 in. below, normal level, and returned to normal level at end of action.	Rose 5/10 in. and returned to normal level.

APPENDIX III.—*continued.*

EXPERIMENTS K—(*continued*).

Description of Test.	Action.	House X, without Intercepting Trap. Movement of Water in Minor Traps.					House Y, with Intercepting Trap, 2¼-in. Seal. Movement of Water in Minor traps.				
		W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor. Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 16/10 ins.	Sink Waste Gully. Normal Water Seal 10/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 15/10 ins.	W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 4/10 ins.	Sink Waste Gully. Normal Water Seal 19/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 16/10 ins.
No. 2. Vent Shaft on Soil Pipe open, "Fresh Air Inlet" closed.	W.C. first floor flushed.	These tests on the house whose drain was without an Intercepting trap, were not carried out, as Test No. 1 showed them to be unnecessary.					At normal level at end of action.	Rose 4/10 in. and returned to normal level.	Rose 1/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.	Rose 4/10 in. and returned to normal level.
	W.C. ground floor flushed.						No movement.	At normal level at end of action.	No movement.	No movement.	No movement.
	Both W.C.'s simultaneously flushed.						At normal level at end of action.	Ditto.	Rose 1/10 in. and returned to normal level.	Rose 1/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.
	Bath emptied, sink waste continuously discharging, and W.C. first floor flushed.						Ditto.	Oscillated between 1/10 in. and 5/10 in. above normal level, and then returned to normal level.	At normal level at end of action.	At normal level at end of action.	Rose 4/10 in. and returned to normal level.
	Bath emptied, sink waste continuously discharging, and W.C. ground floor flushed.						1/10 in. below normal level at end of action.	At normal level at end of action.	Ditto.	Ditto.	No movement.
	Water thrown from bucket down W.C. first floor.	Water at normal level at end of action.	No movement.	Slight oscillation.	No movement.		Violent oscillation. At normal level at end of action.	Rose 6/10 in. and returned to normal level.	Rose 3/10 in. when a small quantity of air was forced through water into atmosphere. At end of action returned to normal level.	Rose 3/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.
	Water thrown from bucket down W.C. ground floor.	No movement.	Water at normal level at end of action.	No movement.	Ditto.		No movement.	Water fell below bridge of trap. At end of action 1 in. below normal level, *i.e.* trap was sealed.	Slight oscillation. At normal level at end of action.	Oscillated between 2/10 in. above and 2/10 in. below normal level. At normal level at end of action.	Slight oscillation. At normal level at end of action.

APPENDIX III.—*continued.*

EXPERIMENTS K—(*continued*).

Description of Test.	Action.	House X, without Intercepting Trap. Movement of Water in Minor Traps.					House Y, with Intercepting Trap, 2¼-in. Seal. Movement of Water in Minor Traps.				
		W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor. Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 16/10 ins.	Sink Waste Gully. Normal Water Seal 10/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 15/10 ins.	W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor. Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 4/10 ins.	Sink Waste Gully. Normal Water Seal 19/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 16/10 ins.
No. 3. Vent Shaft on Soil pipe closed. “Fresh Air Inlet” open.	W.C. first floor flushed.	These tests on the house whose drain was without an Intercepting trap, were not carried out, as Test No. 1 showed them to be unnecessary.					At normal level at end of action.	No movement.	No movement	No movement.	No movement.
	W.C. ground floor flushed.						No movement.	1/10 in. below normal level at end of action.	Ditto.	Ditto.	Ditto.
	Both W.C.'s simultaneously flushed.						At normal level at end of action.	At normal level at end of action.	Rose 2/10 in. and returned to normal level.	Ditto.	Rose 1/10 in. and returned to normal level.
	Bath emptied, sink waste continuously discharging and W.C. 1st floor flushed.						Ditto.	Slight oscillation. At normal level at end of action.	At normal level at end of action.	At normal level at end of action.	No movement.
	Bath emptied, sink waste continuously discharging, and W.C. ground floor flushed.						Slight oscillation at end of action 1/10 ins. below normal level.	At end of action 1/10 in. below normal level.	Ditto.	Ditto.	Ditto.
	Water thrown from bucket down W.C. first floor.	Water fell below bridge of trap. At end of action 16/10 ins. below normal level, *i.e.*, trap only just sealed.	No movement.				Water fell below bridge of trap. At end of action 12/10 ins. below normal level, *i.e.*, trap was sealed.	Rose slightly and returned to 1/10 in. below normal level at end of action.	Slight oscillation. At normal level at end of action.	Slight oscillation. At normal level at end of action.	Slight oscillation. At normal level at end of action.
	Water thrown from bucket down W.C. ground floor.	No movement.	Water at normal level at end of action.				Rose 2/10 ins. and returned to 1/20 in. below normal level.	At end of action fell to 5/10 in. below normal level, and then returned to normal level.	Rose 3/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.	Fell 2/10 in. and returned to normal level.

EXPERIMENTS K—(*continued*).

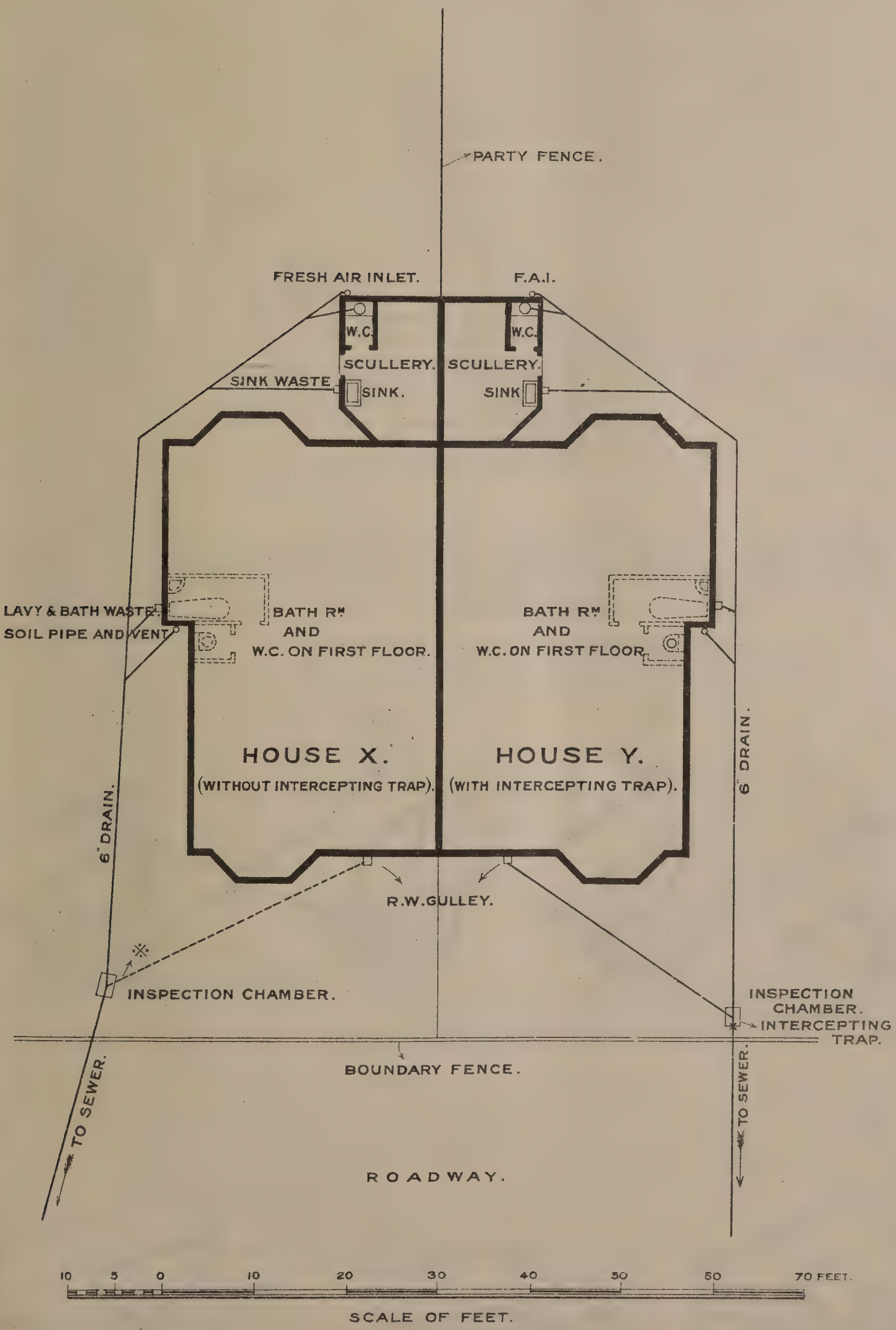
Description of Test.	Action.	House Y, with Intercepting Trap, 2¼-in. Seal. Movement of Water in Minor Traps.				
		W.C. First Floor. Normal Water Seal 16/10 ins.	W.C. Ground Floor. Normal Water Seal 15/10 ins.	Bath and Lavatory Waste Gully. Normal Water Seal 4/10 ins.	Sink Waste Gully. Normal Water Seal 19/10 ins.	Roof Water Gully in Forecourt. Normal Water Seal 16/10 ins.
No. 4. Vent shaft on Soil Pipe and "Fresh air inlet" open.	First floor W.C. flushed.	At normal level at end of action.	No movement.	Rose 1/20 in. and returned to normal level.	No movement.	No movement.
	Ground floor W.C. flushed.	No movement.	At normal level at end of action.	No movement.	Ditto.	Ditto.
	Both W.C.'s simultaneously flushed.	At normal level at end of action.	Ditto.	Rose 1/10 in. and returned to normal level.	Ditto.	Ditto.
	Bath emptied, sink waste continuously discharging, and first floor W.C. flushed.	Ditto.	Rose 3/10 in. and returned to normal level.	At normal level at end of action.	At normal level at end of action.	Ditto.
	Bath emptied, sink waste continuously discharging, and ground floor W.C. flushed.	No movement.	At normal level at end of action.	Ditto.	Ditto.	Ditto.
	Water thrown from bucket down first floor W.C.	At normal level at end of action.	Rose 2/10 in. and returned to normal level.	Rose 1/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.	Rose 2/10 in. and returned to normal level.
	Water thrown from bucket down ground floor W.C.	Slight oscillation 1/10 in. below normal level at end of action.	Water fell below bridge of trap, and returned to 6/10 in. below normal level at end of action.	Slight oscillation. At normal level at end of action.	No movement.	No movement.

APPENDIX III. (CONTINUED).

DIAGRAM III.

EXPERIMENTS AT BRISTOL.

PLAN SHOWING ARRANGEMENT OF DRAINS IN EXPERIMENTS K.



※ This Drain was disconnected at the inspection chamber, in the process of removal of the intercepting trap.

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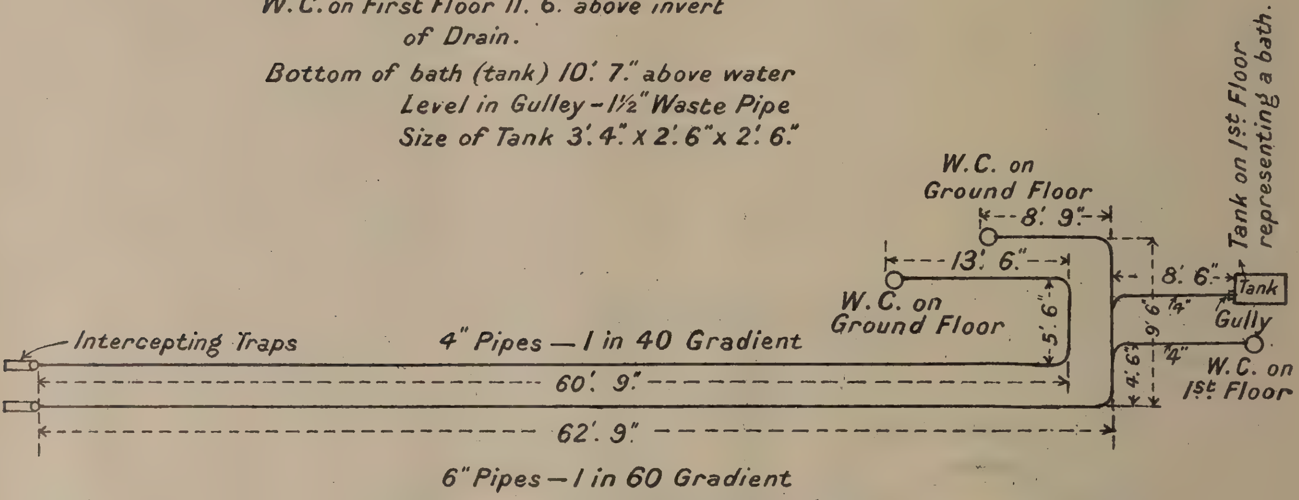
Malby&Sons, Lith.

DIAGRAM IV.

APPENDIX IV.

PLAN SHOWING ARRANGEMENT OF DRAIN PIPES IN EXPERIMENTS CONDUCTED AT ISLINGTON.

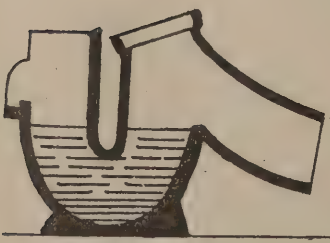
N.B. Each W.C. Supplied with 1¼" Flush Pipe
flushing cistern 4'. 3". above
rim of W.C. basin
W.C. on First Floor 11'. 6." above invert
of Drain.
Bottom of bath (tank) 10'. 7." above water
Level in Gulley – 1½" Waste Pipe
Size of Tank 3'. 4". x 2'. 6" x 2'. 6."



SECTIONS OF TRAPS USED IN EXPERIMENTS AT ISLINGTON.

REDUCED FROM FULL SIZE DIAGRAMS.

No. 1.



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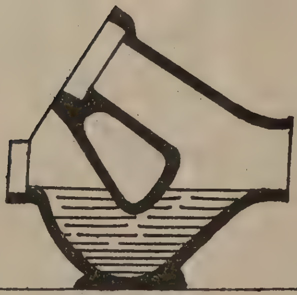

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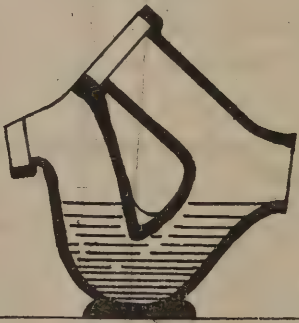

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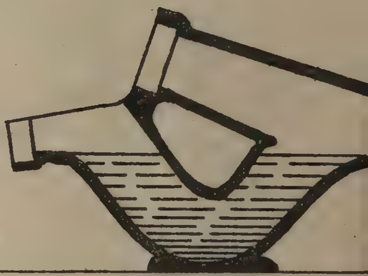

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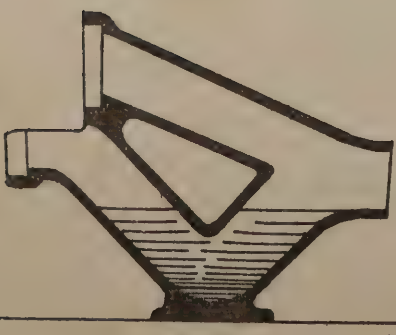

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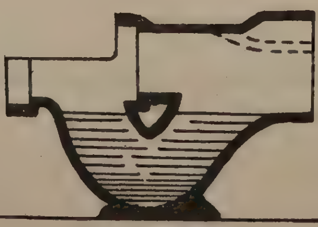

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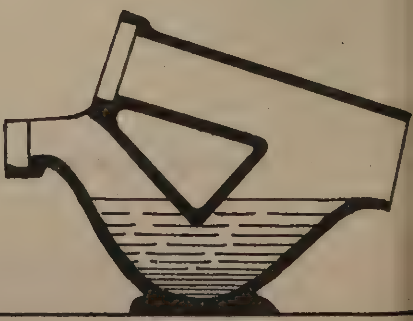

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Malby & Sons, Lith.

APPENDIX IV.

EXPERIMENTS AT ISLINGTON

Carried out by

Mr. J. Patten Barber, Borough Engineer.

These experiments were carried out by Mr. Patten Barber, Engineer to the Borough of Islington, with a view of observing the behaviour of solid matters in sewage in their passage along drains and through various intercepting traps, under conditions as natural as possible. He constructed above ground two separate systems of drains with half-round or channel pipes, 6 in. in diameter in one, and 4 in. in diameter in the other, the former having a uniform gradient of 1 in 60, and the latter one of 1 in 40.

The drains in each case were some 80 ft. in length, and were arranged, as shown in the plan (diagram IV.), with two right-angle bends, with the object of representing drainage systems of artisan dwellings.

On the 6-in. system of drains, a 4-in. branch was connected with a water-closet, the water surface of which was at a height of 11 ft. 6 in. above the invert of the drain, representing a water-closet on the first floor of a house. Another 4-in. branch was connected to a gulley trap, over which discharged a pipe $1\frac{1}{2}$ in. in diameter connected with a tank 3 ft. 4 in. by 2 ft. 6 in., the bottom of which was at a height of 10 ft. 7 in. above the water level in the gulley. This tank was intended to represent a bath on the first floor of a house.

Both the 4-in. and 6-in. systems of drains were each connected at the upper end with a water closet, so as to represent one on the ground floor of a house. Each of the water closets was fitted with a syphonic flushing cistern of 2 gallons capacity, fixed 4 ft. 3 in. above the rim of the water-closet basin. The flushing pipe was $1\frac{1}{4}$ in. in diameter.

Seven types of intercepting traps on the market were used, sections of which are illustrated on diagram IV. Material, composed of clay, tow and Russian tallow, was employed to represent fæcal matter, and usually three pieces of this material, together with three pieces of toilet paper, were inserted in a water closet basin before the flushing cistern was discharged. In most of the experiments, 10 successive discharges of the flushing cistern were made, a fresh batch of artificial fæcal matter and toilet paper being inserted before each flush, and after each flush note was made of the fæcal matter and paper which had passed through the intercepting trap under observation. Until the 10 discharges were completed, any artificial fæcal matter or toilet paper retained in the trap or stranded in the drain was left undisturbed.

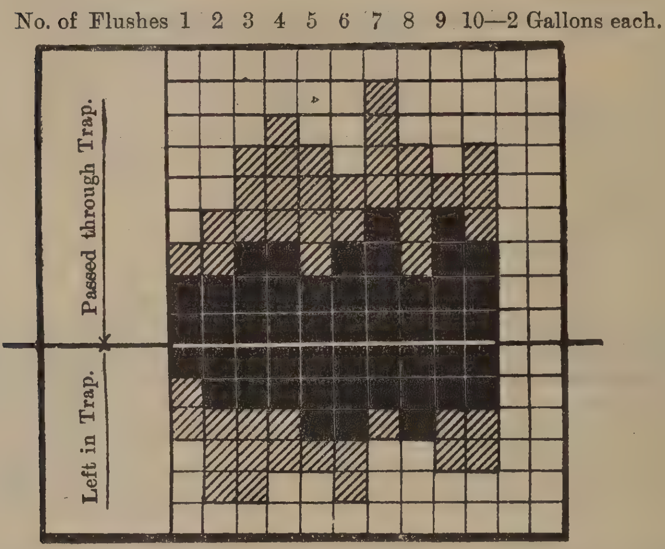
The results of many of these experiments are given in detail in the following tables, and in ten typical cases diagrams are also given which show graphically what took place after each of the 10 successive discharges from the water closet flushing cistern.

Besides the seven types of intercepting traps used, observations were also made with certain experimental traps constructed by Mr. Barber. The results of the observations with three of these traps, one 4 in. in diameter, another $3\frac{1}{2}$ in. in diameter, and a third 3 in. in diameter are shown in tables (with diagrams) 20, 21 and 22.

For references to these Islington experiments in the text of the report, see pars. 14 to 17, 29 to 32.

APPENDIX IV.—*continued.*

4-in. TRAP No. 1—
1 in 40 GRADIENT—4-in. DRAIN PIPES—2¼-in. SEAL—2⅛-in. CASCADE—4½ Pts. CAPACITY.



In the diagrams, on this and subsequent pages, each black square represents fæcal matter, and each hatched square represents paper.

TABLE No. 1.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.†	F.*	P.†	F.*	P.†	F.*	P.†	
1	2 gallon W.C. flush -	3	3	3	3	2	1	1	2	
2	" " " -	3	3	4	5	2	2	2	3	
3	" " " -	3	3	5	6	3	3	2	3	
4	" " " -	3	3	5	6	3	4	2	2	
5	" " " -	3	3	5	5	2	4	3	1	
6	" " " -	3	3	6	4	3	2	3	2	
7	" " " -	3	3	6	5	4	4	2	1	
8	" " " -	3	3	5	4	2	4	3	0	
9	" " " -	3	3	6	3	4	1	2	2	
10	" " " -	3	3	5	5	3	3	2	2	
	TOTALS - -	30	30	50	46	28	28	22	18	
	‡AVERAGE RESULT -	-		-		58 %		42 %		

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* F. represents artificial fæcal matter (see page 59).

† P. represents toilet-paper.

‡ Expressed as a percentage of the total solids in the intercepting trap during each flush.

APPENDIX IV.—*continued.*

4-in. TRAP No. 2—
1 in 40 GRADIENT—4-in. DRAIN PIPES—3¾-in. SEAL NO CASCADE—5½ Pts. CAPACITY.

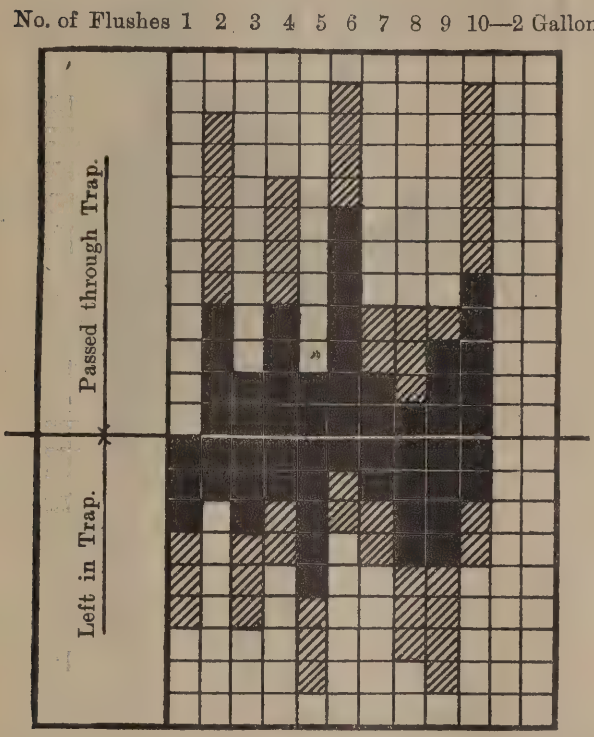

TABLE No. 2.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	Nil		3	3	
2	" " " -	3	3	6	6	4	6	2	0	
3	" " " -	3	3	5	3	2	0	3	3	
4	" " " -	3	3	6	6	4	4	2	2	
5	" " " -	3	3	5	5	0	2	5	3	
6	" " " -	3	3	8	6	7	4	1	2	
7	" " " -	3	2	4	4	2	2	2	2	One P. did not reach trap.
8	" " " -	3	4	5	6	1	3	4	3	
9	" " " -	3	3	7	5	3	1	4	4	" " "
10	" " " -	3	3	7	8	5	6	2	2	
	TOTALS - - -	30	30	56	52	28	28	28	24	
	*AVERAGE RESULT -	-		-		51 %		49 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

4-in. TRAP No. 3—
1 in 40 GRADIENT—6-in. DRAIN PIPES—$2\frac{1}{4}$-in. SEAL—
$4\frac{1}{4}$-in. CASCADE—$4\frac{3}{4}$ Pts. CAPACITY.

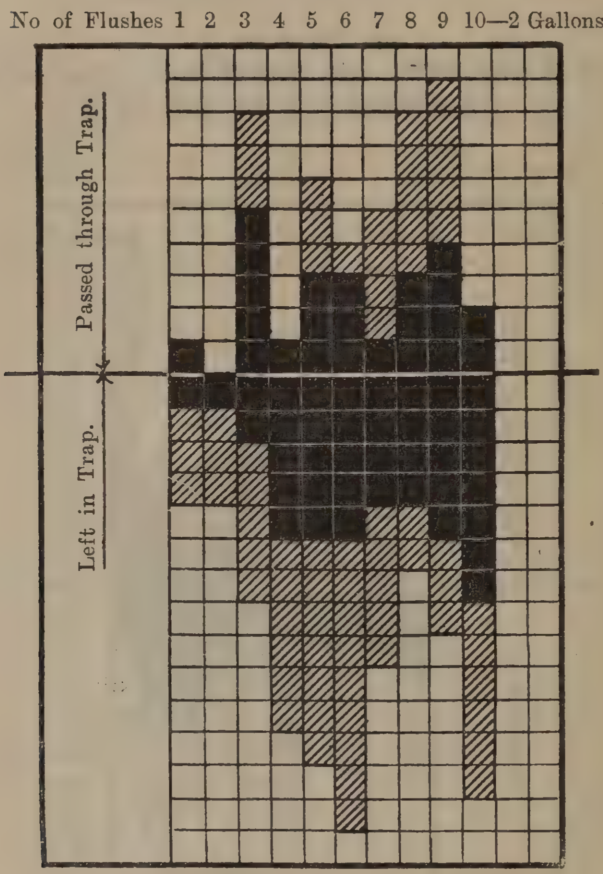

TABLE No. 3.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush on first floor	3	3	2	3	1	0	1	3	One F. did not reach trap.
2	,, ,, ,, ,,	3	1	1	3	Nil		1	3	Four F. and three P. did not reach trap.
3	,, ,, ,, ,,	3	4	7	8	5	3	2	5	One F. and one P. did not reach trap.
4	,, ,, ,, ,,	3	2	6	6	1	0	5	6	Three P. did not reach trap.
5	,, ,, ,, ,,	3	3	8	10	3	3	5	7	Two P. ,, ,,
6	,, ,, ,, ,,	3	3	8	10	3	1	5	9	,, ,, ,,
7	,, ,, ,, ,,	3	2	5	9	1	4	4	5	Three F. and five P. did not reach trap.
8	,, ,, ,, ,,	3	3	7	7	3	5	4	2	Three F. and six P. did not reach trap.
9	,, ,, ,, ,,	3	3	9	8	4	5	5	3	One F. and three P. did not reach trap.
10	,, ,, ,, ,,	3	6	9	6	2	0	7	6	Three P. did not reach trap.
	TOTALS - -	30	30	62	70	23	21	39	49	
	*AVERAGE RESULT -	-		-		33 %		67 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 4.

4 in. TRAP No. 3— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2¼-in. SEAL— 4¼-in. CASCADE—4¾ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush. Solids through Trap.		Effect of Flush. Solids left in Trap.		REMARKS.
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	3 gallon W.C. flush -	3	3	3	2	2	1	1	1	One P. did not reach trap
2	,, ,, ,, -	3	3	4	4	4	1	0	3	,, ,, ,,
3	,, ,, ,, -	3	3	3	7	2	2	1	5	
4	,, ,, ,, -	3	3	4	8	3	5	1	3	
5	,, ,, ,, -	3	3	4	6	4	3	0	3	
6	,, ,, ,, -	3	3	3	6	1	4	2	2	
7	,, ,, ,, -	3	3	5	5	3	2	2	3	
8	,, ,, ,, -	3	3	5	6	5	3	0	3	
9	,, ,, ,, -	3	3	3	6	2	3	1	3	
10	,, ,, ,, -	3	3	4	6	2	5	2	1	
	TOTALS - -	30	30	38	56	28	29	10	27	
	*AVERAGE RESULT -	-		-		60 %		40 %		

TABLE No. 5.

4-in. TRAP No. 3— FITTED TO 6-in. DRAIN WITH 6-in. TO 4-in. REVERSED TAPER PIPE—1 in 40 GRADIENT— 2½-in. SEAL—4¼-in. CASCADE—5¼ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush. Solids through Trap.		Effect of Flush. Solids left in Trap.		REMARKS.
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	2	3	1	1	0	2	1	Two P. did not reach trap.
2	,, ,, ,, -	3	3	5	5	2	1	3	4	One ,, ,,
3	,, ,, ,, -	3	3	6	8	3	3	3	5	
4	,, ,, ,, -	3	3	6	8	3	1	3	7	
5	,, ,, ,, -	3	3	6	10	5	5	1	5	
6	,, ,, ,, -	3	3	3	6	2	1	1	5	One F. and two P. did not reach trap.
7	,, ,, ,, -	3	3	5	9	2	5	3	4	One P. did not reach trap.
8	,, ,, ,, -	3	3	5	7	3	0	2	7	One F. and one P. did not reach trap.
9	,, ,, ,, -	3	2	6	10	2	3	4	7	One P. did not reach trap.
10	,, ,, ,, -	3	4	6	8	5	3	1	5	One F. and three P. did not reach trap.
	TOTALS - -	30	30	51	72	28	22	23	50	
	*AVERAGE RESULT -	-		-		48 %		52 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

4-in. TRAP No. 4—
1 in 40 GRADIENT—4-in. DRAIN PIPES—3¼-in. SEAL—¾-in. CASCADE—7 Pts. CAPACITY.

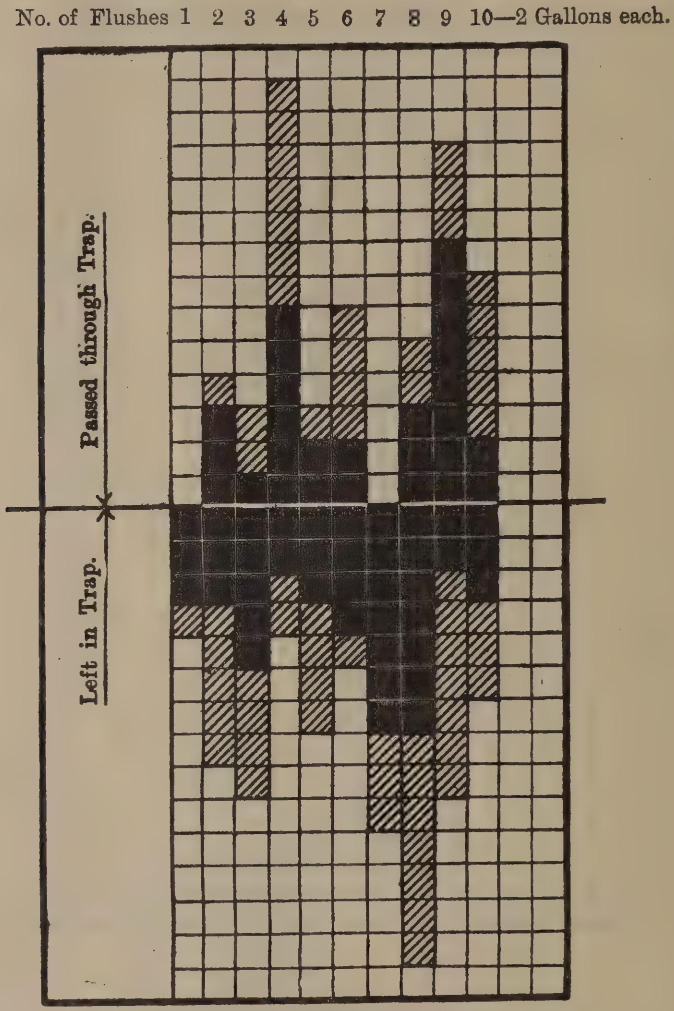

TABLE No. 6.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	2	3	1	Nil		3	1	Two P. did not reach trap.
2	„ „ „ -	3	4	6	6	3	1	3	5	
3	„ „ „ -	3	3	6	6	1	2	5	4	„ „ „
4	„ „ „ -	3	3	8	9	6	7	2	2	
5	„ „ „ -	3	3	5	5	2	1	3	4	
6	„ „ „ -	3	1	6	5	2	4	4	1	„ „ „
7	„ „ „ -	3	2	7	3	Nil		7	3	Three P. „ „
8	„ „ „ -	3	6	10	9	3	2	7	7	
9	„ „ „ -	3	3	10	10	8	3	2	7	
10	„ „ „ -	3	2	5	8	2	5	3	3	Two P. „ „
	TOTALS - -	30	29	66	62	27	25	39	37	
	*AVERAGE RESULT-	-		-		40 %		60 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 7.

4-in. TRAP No. 4— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2½-in. SEAL— 2-in. CASCADE—6 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	1	2	0	Nil		2	0	One F. and three P. did not reach trap.
2	,, ,, ,, -	3	3	6	4	1	0	5	4	Two P. did not reach trap.
3	,, ,, ,, -	3	5	8	9	4	0	4	9	
4	,, ,, ,, -	3	1	7	10	3	3	4	7	,, ,, ,, ,,
5	,, ,, ,, -	3	5	7	10	2	0	5	10	,, ,, ,, ,,
6	,, ,, ,, -	3	2	8	14	6	4	2	10	One ,, ,, ,,
7	,, ,, ,, -	3	2	5	12	1	4	4	8	Two ,, ,, ,,
8	,, ,, ,, -	3	3	7	11	2	0	5	11	,, ,, ,, ,,
9	,, ,, ,, -	3	4	8	15	2	2	6	13	One ,, ,, ,,
10	,, ,, ,, -	3	3	9	16	1	0	8	16	,, ,, ,, ,,
	TOTALS - -	30	29	67	101	22	13	45	88	
	*AVERAGE RESULT -	-		-		21 %		79 %		

TABLE No. 8.

4-in. TRAP No. 4— 1 in 40 GRADIENT—4-in. DRAIN PIPES—3½-in. SEAL— 1⅝-in. CASCADE—6½ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush - - - -	3	3	3	3	0	1	3	2	
2	,, ,, ,, - - - -	3	3	6	5	5	3	1	2	
3	,, ,, ,, - - - -	3	3	4	5	3	1	1	4	
4	,, poured from pail into W.C. (ground floor)	Nil		1	4	Nil		1	4	No solids added.
5	,, W.C. flush (ground floor)	,,		1	4	1	1	0	3	,, ,,
6	,, ,, ,, and two gallons from pail	,,		0	3	0	2	0	1	,, ,,
7	,, W.C. flush - - -	3	3	3	3	Nil		3	3	
8	,, ,, ,, - - - -	3	3	6	6	3	2	3	4	
9	,, ,, ,, - - - -	3	3	6	7	4	4	2	3	
10	,, from pail poured into W.C.	Nil		2	3	1	0	1	3	,, ,,
11	,, W.C. flush - - -	,,		1	3	0	1	1	2	,, ,,
12	,, each from W.C. and pail -	,,		1	2	1	2	Nil		,, ,,
13	,, W.C. flush - - -	3	3	3	3	Nil		3	3	
14	,, ,, ,, - - - -	3	3	6	6	5	1	1	5	
15	,, ,, ,, - - - -	3	3	4	8	1	0	3	8	
16	,, from pail poured into W.C.	Nil		3	8	Nil		3	8	,, ,,
17	,, W.C. flush - - -	,,		3	8	1	0	2	8	,, ,,
18	,, each from W.C. and pail -	,,		2	8	2	7	0	1	,, ,,
19	3 gallon W.C. flush - - -	3	3	3	3	1	0	2	3	
20	,, ,, ,, - - - -	3	3	5	6	2	0	3	6	
21	,, ,, ,, - - - -	3	3	6	9	6	6	0	3	
22	,, ,, ,, - - - -	3	3	3	6	2	0	1	6	
23	,, ,, ,, - - - -	3	3	4	9	4	8	0	1	
24	,, ,, ,, - - - -	3	2	3	3	0	1	3	2	One P. did not reach trap
25	,, ,, ,, - - - -	3	4	6	6	3	2	3	4	
26	,, ,, ,, - - - -	3	3	6	7	3	0	3	7	
27	,, ,, ,, - - - -	3	3	6	10	5	0	1	10	
28	,, ,, ,, - - - -	3	2	4	12	1	3	3	9	,, ,, ,,
	TOTALS (Flushes 19–28) -	30	29	46	71	27	20	19	51	
	*AVERAGE RESULT - -	—		—		40%		60%		

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* See footnote on page 60.

Appendix IV.—*continued.*

4-in. TRAP No. 5—
1 in 40 GRADIENT—4-in. DRAIN PIPES—2-in. SEAL—
4½-in. CASCADE—4 Pts. CAPACITY.

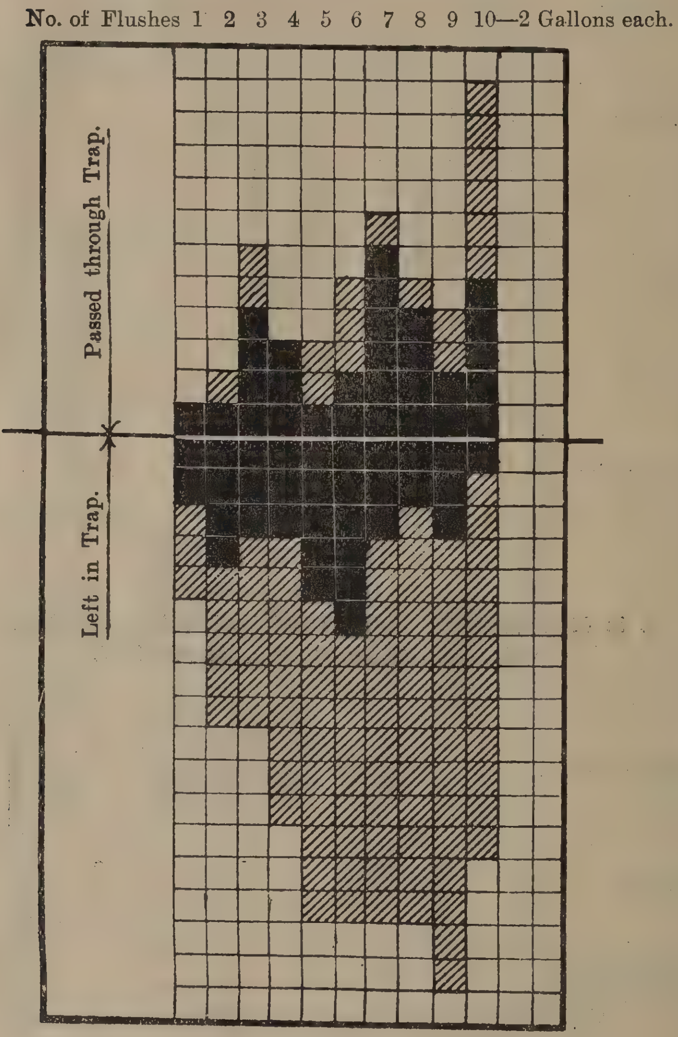

TABLE No. 9.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				Remarks.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	1	0	2	3	
2	„ „ „ -	3	3	5	6	1	1	4	5	
3	„ „ „ -	3	3	7	8	4	2	3	6	
4	„ „ „ -	3	3	6	9	3	0	3	9	
5	„ „ „ -	3	3	6	12	1	2	5	10	
6	„ „ „ -	3	2	8	12	2	3	6	9	One P. did not reach trap.
7	„ „ „ -	3	4	9	13	6	1	3	12	
8	„ „ „ -	3	3	6	14	4	1	2	13	„ „ „
9	„ „ „ -	3	3	5	16	2	2	3	14	„ „ „
10	„ „ „ -	3	3	6	18	5	6	1	12	
	Totals -	30	30	61	111	29	18	32	93	
	*Average Result-	-		-		27 %		73 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 10.

4-in. TRAP No. 6— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2⅛-in. SEAL— ¾-in. CASCADE—5¾ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	1	0	2	3	
2	,, ,, ,, -	3	3	5	6	0	4	5	2	
3	,, ,, ,, -	3	3	8	5	2	2	6	3	
4	,, ,, ,, -	3	2	9	5	4	1	5	4	One P. did not reach trap.
5	,, ,, ,, -	3	4	8	8	3	5	5	3	
6	,, ,, ,, -	3	1	8	4	2	1	6	3	Two ,, ,,
7	,, ,, ,, -	3	4	9	7	2	5	7	2	One ,, ,,
8	,, ,, ,, -	2	4	9	6	2	4	7	2	,, F. ,, ,,
9	,, ,, ,, -	4	3	11	5	2	2	9	3	
10	,, ,, ,, -	3	2	12	5	4	3	8	2	,, P. ,, ,,
	TOTALS - -	30	29	82	54	22	27	60	27	
	*AVERAGE RESULT -	-		-		36 %		64 %		

TABLE No. 11.

4-in. TRAP No. 6— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2¼-in. SEAL— 1-in. CASCADE—5 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	2	Nil		3	2	One P. did not reach trap.
2	,, ,, ,, -	3	3	6	6	5	1	1	5	
3	,, ,, ,, -	3	3	4	8	0	2	4	6	
4	,, ,, ,, -	3	2	4	6	0	1	4	5	Three F. and three P. did not reach trap.
5	,, ,, ,, -	3	4	10	11	4	1	6	10	
6	,, ,, ,, -	3	2	9	12	5	1	4	11	One P. did not reach trap.
7	,, ,, ,, -	3	3	7	14	4	4	3	10	,, ,, ,,
8	,, ,, ,, -	3	2	6	12	5	1	1	11	Two ,, ,,
9	,, ,, ,, -	3	5	4	16	0	2	4	14	
10	,, ,, ,, -	3	3	7	17	1	2	6	15	
	TOTALS - -	30	30	60	104	24	15	36	89	
	*AVERAGE RESULT -	-		-		24 %		76 %		

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* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 12.

4-in. TRAP No. 6— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2¼-in. SEAL— 1¼-in. CASCADE—4½ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				Remarks.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	0	1	3	2	
2	,, ,, ,, -	3	3	6	5	Nil		6	5	
3	,, ,, ,, -	3	3	9	8	1	0	8	8	
4	,, ,, ,, -	3	3	11	11	4	7	7	4	
5	,, ,, ,, -	3	3	10	7	3	2	7	5	
6	,, ,, ,, -	3	3	10	8	7	6	3	2	
7	,, ,, ,, -	3	3	6	5	5	2	1	3	
8	,, ,, ,, -	3	3	4	6	1	4	3	2	
9	,, ,, ,, -	3	2	5	3	Nil		5	3	One F. and two P. did not reach trap.
10	,, ,, ,, -	3	4	9	8	6	7	3	1	
	TOTALS - -	30	30	73	64	27	29	46	35	
	*AVERAGE RESULT -	-		-		41 %		59 %		

TABLE No. 13.

4 in. TO 6-in. TAPER TRAP No. 7— 1 in 60 GRADIENT—6-in. DRAIN PIPES—1¾-in. SEAL— 3¼-in. CASCADE—9 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				Remarks.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	2	Nil		3	2	One P. did not reach trap.
2	,, ,, ,, -	3	3	6	5	1	0	5	5	,, ,, ,,
3	,, ,, ,, -	3	3	8	8	2	0	6	8	,, ,, ,,
4	,, ,, ,, -	3	2	9	11	1	0	8	11	,, ,, ,,
5	,, ,, ,, -	3	4	11	14	5	0	6	14	,, ,, ,,
6	,, ,, ,, -	3	2	9	17	1	2	8	15	,, ,, ,,
7	,, ,, ,, -	3	4	11	19	4	1	7	18	
8	,, ,, ,, -	3	2	10	19	2	3	8	16	Two ,, ,,
9	,, ,, ,, -	3	4	11	20	3	1	8	19	One ,, ,,
10	,, ,, ,, -	3	3	11	22	5	0	6	22	,, ,, ,,
	TOTALS - -	30	30	89	137	24	7	65	130	
	*AVERAGE RESULT -	-		-		14 %		86 %		
11	Effect of bath discharge— 24 gallons from bath on 1st floor—1½ in. discharge pipe - -	Nil		6	23	6	10	0	13	

* See footnote on page 60.

APPENDIX IV.—*continued.*

6-in. TRAP No. 2—
1 in 60 GRADIENT—6-in. DRAIN PIPES—2½-in. SEAL—¾-in. CASCADE—10½ Pts. CAPACITY.

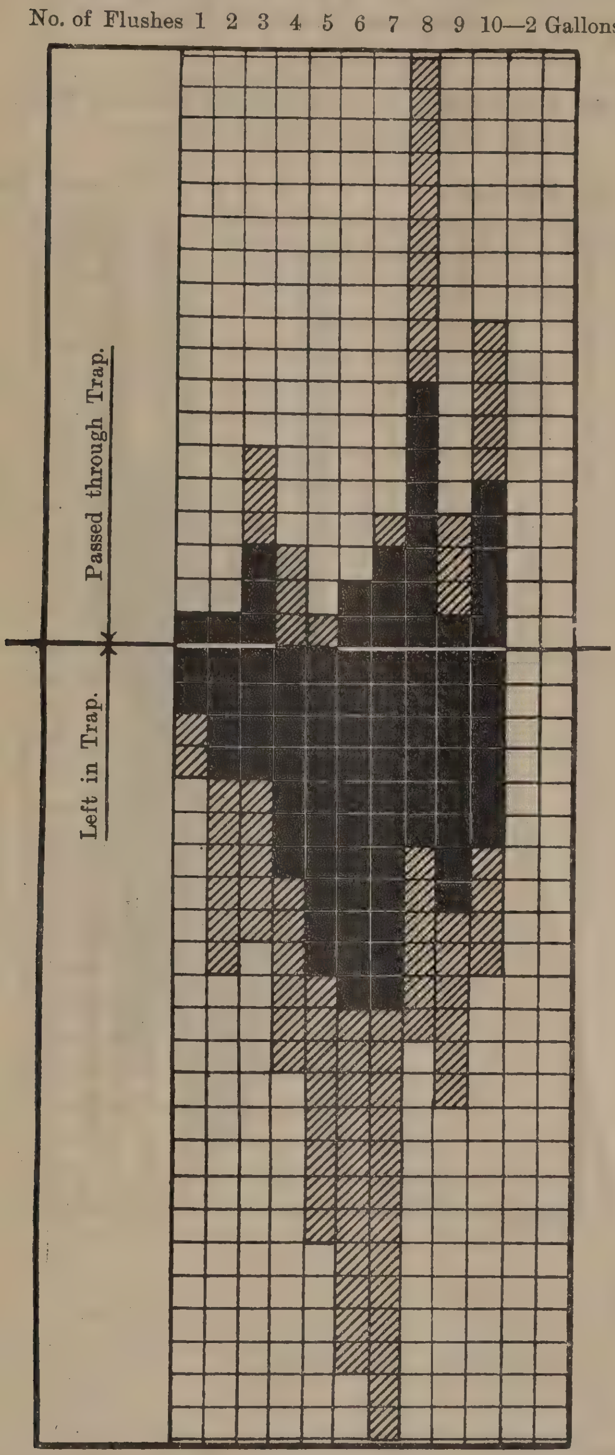

TABLE No. 14.

No. of Flush.	Description of Flush.	Solids discharged from W.C. F.*	Solids discharged from W.C. P.*	Total Solids in Intercepting Trap during Flush. F.	Total Solids in Intercepting Trap during Flush. P.	Effect of Flush. Solids through Trap. F.	Effect of Flush. Solids through Trap. P.	Effect of Flush. Solids left in Trap. F.	Effect of Flush. Solids left in Trap. P.	REMARKS.
1	2 gallon W.C. flush -	3	2	3	2	1	0	2	2	One P. did not reach trap.
2	,, ,, ,, -	3	4	5	6	1	0	4	6	
3	,, ,, ,, -	3	2	7	8	3	3	4	5	,, ,, ,,
4	,, ,, ,, -	3	4	7	9	0	3	7	6	
5	,, ,, ,, -	3	3	10	9	0	1	10	8	
6	,, ,, ,, -	3	3	13	11	2	0	11	11	
7	,, ,, ,, -	3	3	14	14	3	1	11	13	
8	,, ,, ,, -	3	3	14	16	8	10	6	6	
9	,, ,, ,, -	3	3	9	9	1	3	8	6	
10	,, ,, ,, -	3	3	11	9	5	5	6	4	
	TOTALS - -	30	30	93	93	24	26	69	67	
	*AVERAGE RESULT-	-		-		27 %		73 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

6-in. TRAP No. 3—
1 in 60 GRADIENT—6-in. DRAIN PIPES—3-in. SEAL—
3-in. CASCADE—10 Pts. CAPACITY.

No. of Flushes 1 2 3 4 5 6 7 8 9 10 11—10 2-Gallons; 1 30-Gallons.

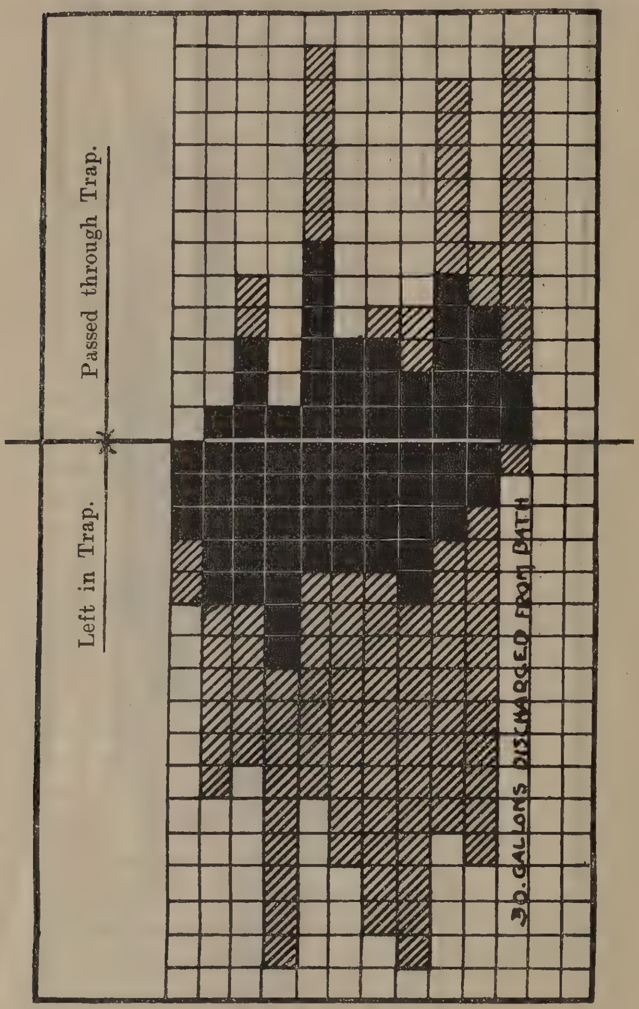

TABLE No. 15.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	3 gallon W.C. flush -	3	3	3	2	Nil		3	2	One P. did not reach trap.
2	,, ,, ,, -	3	3	6	6	1	0	5	6	
3	,, ,, ,, -	3	3	8	7	3	2	5	5	Two P. ,, ,,
4	,, ,, ,, -	3	2	8	9	1	0	7	9	One P. ,, ,,
5	,, ,, ,, -	3	4	10	13	6	6	4	7	
6	,, ,, ,, -	3	2	7	9	3	0	4	9	,, ,, ,,
7	,, ,, ,, -	3	3	7	12	3	1	4	11	,, ,, ,,
8	,, ,, ,, -	3	3	7	13	2	2	5	11	Two P. ,, ,,
9	,, ,, ,, -	3	4	8	15	5	6	3	9	One P. ,, ,,
10	,, ,, ,, -	3	3	6	13	4	2	2	11	
	TOTALS - -	30	30	70	99	28	19	42	80	
	*AVERAGE RESULT-	/	-		-	28 %		72 %		
11	Effect of bath discharge— 30 gallons discharged from bath on first floor	Nil		2	11	2	10	0	1	

* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 16.

6-in. TRAP No. 3—
1 in 60 GRADIENT—6-in. DRAIN PIPES—3-in. SEAL—
3-in. CASCADE—10 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	2	3	1	Nil		3	1	Two P. did not reach trap.
2	,, ,, ,, -	3	2	5	4	1	0	4	4	One F. and two P. did not reach trap.
3	,, ,, ,, -	3	4	8	8	3	0	5	8	One P. did not reach trap.
4	,, ,, ,, -	3	4	8	11	2	2	6	9	,, ,, ,,
5	,, ,, ,, -	3	3	9	13	5	1	4	12	
6	,, ,, ,, -	3	3	7	15	3	4	4	11	
7	,, ,, ,, -	3	3	7	13	3	1	4	12	,, ,, ,
8	,, ,, ,, -	3	3	7	16	1	1	6	15	
9	,, ,, ,, -	3	2	9	17	1	4	8	13	,, ,, ,,
10	,, ,, ,, -	3	4	11	16	6	3	5	13	,, ,, ,,
	TOTALS - -	30	30	74	114	25	16	49	98	
	*AVERAGE RESULT -	-		-		22 %		78 %		

TABLE No. 17.

6-in. TRAP No. 3—
1 in 60 GRADIENT—6-in. DRAIN PIPES—3-in. SEAL—
3-in. CASCADE—10 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush on 1st floor -	2	3	2	3	Nil		2	3	One F. did not reach trap.
2	,, ,, ,, -	4	3	6	6	2	0	4	6	
3	,, ,, ,, -	3	3	7	9	2	0	5	9	
4	,, poured from pail into W.C. -	Nil		5	9	Nil		5	9	No solids washed out of trap.
5	,, ,, ,, ground floor -	,,		5	9	,,		5	9	,, ,, ,,
6	,, W.C. flush on ground floor -	,,		5	9	,,		5	9	,, ,, ,,
7	,, W.C. flush on 1st floor -	,,		5	9	,,		5	9	,, ,, ,,
8	,, W.C. flush and 2-gallons from pail, 1st floor -	,,		5	9	1	3	4	6	
9	,, ,, ,, ground floor -	,,		4	6	3	6	1	0	

* See footnote on page 60.

APPENDIX IV.—*continued.*

TABLE No. 18.

6-in. TRAP No. 3—
1 in 60 GRADIENT—6-in. DRAIN PIPES—3-in. SEAL—
3-in. CASCADE—10 Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush. Solids through Trap.		Effect of Flush. Solids left in Trap.		REMARKS.
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush 1st floor -	3	2	3	1	Nil		3	1	Two P. did not reach trap.
2	,, ,, ,, -	3	2	6	4	1	0	5	4	,, ,, ,,
3	,, ,, ,, -	3	4	8	7	2	0	6	7	,, ,, ,,
4	,, from pail poured in W.C. 1st floor	0	1	6	9	1	0	5	9	No solids added.
5	,, from pail poured in W.C. ground floor	Nil		5	9	1	0	4	9	,, ,,
6	,, W.C. flush ground floor	,,		4	9	2	0	2	9	,, ,,
7	,, W.C. flush 1st floor -	,,		2	9	Nil		2	9	,, ,,
8	,, from pail and 2 gals. W.C. flush 1st floor	,,		2	9	,,		2	9	,, ,,
9	,, from pail and 2 gals. W.C. flush ground floor	,,		2	9	1	6	1	3	,, ,,
	TOTALS - - -	9	9	38	66	8	6	30	60	

TABLE No. 19.

6-in. TRAP No. 1—
1 in 60 GRADIENT—6-in. DRAIN PIPES—$2\frac{1}{2}$-in. SEAL—
$3\frac{7}{8}$-in. CASCADE—$9\frac{1}{2}$ Pts. CAPACITY.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush. Solids through Trap.		Effect of Flush. Solids left in Trap.		REMARKS.
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	2	1	Nil		2	1	One F. and two P. did not reach trap.
2	,, ,, ,, -	3	3	6	6	1	0	5	6	
3	,, ,, ,, -	3	3	8	9	0	1	8	8	
4	,, ,, ,, -	3	3	10	10	2	4	8	6	One F. and one P. did not reach trap.
5	,, ,, ,, -	3	3	12	10	4	1	8	9	
6	,, ,, ,, -	3	3	11	12	3	6	8	6	
7	,, ,, ,, -	3	3	11	9	2	2	9	7	
8	,, ,, ,, -	3	3	12	10	3	5	9	5	
9	,, ,, ,, -	3	3	12	7	1	1	11	6	One P. did not reach trap.
10	,, ,, ,, -	3	3	14	10	5	4	9	6	
	TOTALS - -	30	30	98	84	21	24	77	60	
	*AVERAGE RESULT -	-		-		25 %		75 %		

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* See footnote on page 60.

APPENDIX IV.—*continued.*

4-in. EXPERIMENTAL TRAP—
1 in 40 GRADIENT—4-in. DRAIN PIPES—2-in. SEAL—
NO CASCADE—6 Pts. CAPACITY.

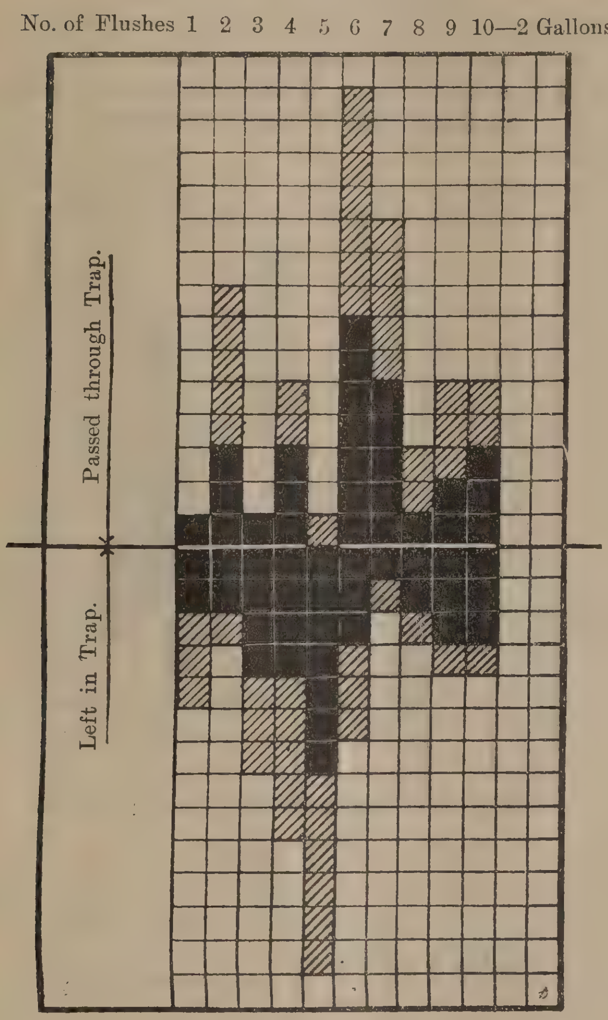

TABLE No. 20.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush. Solids through Trap.		Effect of Flush. Solids left in Trap.		REMARKS.
		F.*	P *	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	1	0	2	3	
2	,, ,, ,, -	3	3	5	6	3	5	2	1	
3	,, ,, ,, -	3	3	5	3	1	0	4	3	One P. did not reach trap.
4	,, ,, ,, -	3	3	7	7	3	2	4	5	
5	,, ,, ,, -	3	3	7	7	0	1	7	6	,, ,, ,,
6	,, ,, ,, -	3	3	10	10	7	7	3	3	
7	,, ,, ,, -	3	3	6	6	5	5	1	1	
8	,, ,, ,, -	2	3	3	3	1	2	2	1	One P. and one F. did not reach trap.
9	,, ,, ,, -	4	3	5	4	2	3	3	1	One F. did not reach trap.
10	,, ,, ,, -	3	2	6	3	3	2	3	1	One P. ,, ,,
	TOTALS - -	30	29	57	52	26	27	31	25	
	*AVERAGE RESULT-	-		-		49 %		51 %		

* See footnote on page 60.

APPENDIX IV.—*continued.*

3½-in. EXPERIMENTAL TRAP— 1 in 40 GRADIENT—4-in. DRAIN PIPES—2-in. SEAL— NO CASCADE—4 Pts. CAPACITY.

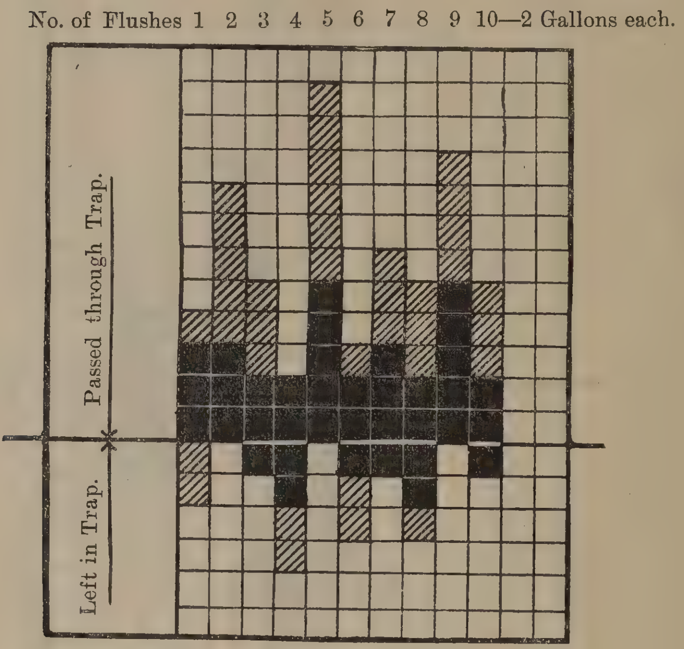

TABLE No. 21.

No. of Flush.	Description of Flush.	Solids discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				REMARKS.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	3	1	0	2	
2	,, ,, ,, -	3	3	3	5	3	5	Nil		
3	,, ,, ,, -	3	3	3	3	2	3	1	0	
4	,, ,, ,, -	3	2	4	2	2	0	2	2	One P. did not reach trap.
5	,, ,, ,, -	3	4	5	6	5	6	Nil		
6	,, ,, ,, -	3	3	3	3	2	1	1	2	
7	,, ,, ,, -	3	1	4	3	3	3	1	0	Two P. ,, ,,
8	,, ,, ,, -	3	5	4	4	2	3	2	1	One P. ,, ,,
9	,, ,, ,, -	3	3	5	4	5	4	Nil		
10	,, ,, ,, -	3	3	3	3	2	3	1	0	
	TOTALS - -	30	30	37	36	29	29	8	7	
	*AVERAGE RESULT-	-		-		80 %		20 %		

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* See footnote on page 60.

Appendix IV.—*continued.*

3-in. EXPERIMENTAL TRAP—
1 in 40 GRADIENT—4-in. DRAIN PIPES—2-in. SEAL—
1-in. CASCADE—2½ Pts. CAPACITY.

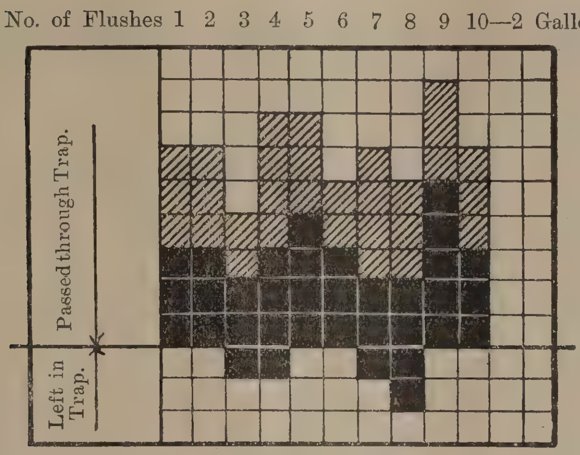

TABLE No. 22.

No. of Flush.	Description of Flush.	Solids Discharged from W.C.		Total Solids in Intercepting Trap during Flush.		Effect of Flush.				Remarks.
						Solids through Trap.		Solids left in Trap.		
		F.*	P.*	F.	P.	F.	P.	F.	P.	
1	2 gallon W.C. flush -	3	3	3	3	3	3	Nil		
2	” ” ” -	3	3	3	3	3	3	”		
3	” ” ” -	3	3	3	2	2	2	1	0	One P. did not reach trap.
4	” ” ” -	3	3	4	4	3	4	1	0	
5	” ” ” -	3	3	4	3	4	3	Nil		
6	” ” ” -	3	3	3	2	3	2	”		One P. ” ” ” ”
7	” ” ” -	3	3	3	4	2	4	1	0	
8	” ” ” -	3	3	4	3	2	3	2	0	
9	” ” ” -	3	3	5	3	5	3	Nil		
10	” ” ” -	3	3	3	3	3	3	”		
	Totals - -	30	30	35	30	30	30	5	0	
	*Average Result-	-		-		92 %		8 %		

* See footnote on page 60.

APPENDIX V.

Professor **DELÉPINE'S EXPERIMENTS** in **MANCHESTER.**

SUMMARY OF THE EFFECTS OF EXPOSURES OF THE SAME DURATION TO SEWER AIR AND GARDEN AIR UPON THE WEIGHT OF 34 ANIMALS.*

Group.	Time of Year.	Particulars of Exposures.		Kind of Animal and State.	Sewer Air Experiments.		Garden Air Experiments.		Mortality up to January, 1909.†	
		Duration of Exposure in Experimental Cages.	Quantity of Air passed through Cages per day (Litres).		Original Weight in ozs.	Weight at end. Original being 100	Weight at end. Original being 100	Original Weight in ozs.	Sewer Air.	Garden Air.
		Days.							No. of days †	No. of days.†
1	July	38	2280—8550	Kittens	24	170·7	181·7	23	Living 186	Living 186
	August			healthy	26	179·8	181·7	23	Living 186	Living 186
2	October	7	3450—6150	Kittens	28	86	92.2	38	Dead 20	Dead 20
				diseased	24	116·6	71·2	42	Dead 21	Dead 22
3	July	38	2280—8550	Rabbits	25	128	138	26	Dead 88	Living 88
	August			healthy	25	130	113·5	22	Dead 88	Dead 55
4	December	15	3900—4575	Rabbits	20	125	132	18	Living 23	Dead 23
				healthy	17	132	149	12	Dead 23	Dead 20
5	July	38	2280—8550	Guinea pigs	28	100	95·7	23	Dead 86	Dead 58
	August				6	200	149·9	8	Dead 105	Dead 110
6	October	32	3600—6450	Diseased	6·5	138·5	122·2	9	Dead 53	Dead 52
	November			Guinea pigs	10	125	156·1	8	Dead 44	Dead 53
	December									
7	October	83	3600—6450	Guinea pigs	9	183·2	137·5	8	Living 98	Dead 67
	November				8	225	180	10	Living 98	Living 98
	December									
8	December	12	3900—4575	Guinea pigs	8	100	100	9	Living 20	Living 20
					7	114	114	7	Living 20	Living 20
9	December	12	3900—4575	Guinea pigs	16	94	93	14	Living 20	Living 20
									8 Living 9 Dead	7 Living 10 Dead

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* The 15 animals still living when this part of the report was written were kept afterwards under observation for periods varying between 1 month and 6 months. No new features were revealed by these observations. The 4 healthy kittens of group 1 were used for a special experiment. On the 28th of August, 1908, they were all given at one meal 3½ ozs. of tuberculous cows' milk; one of these, which had been exposed to sewer air, received a double dose (7 ozs.). These kittens were again given, on September 5th, 8 ozs. of tuberculous cows' milk. As will be seen by the table, 2 of these kittens had been exposed to sewer air for 38 days. The one who had received a double dose of tuberculous milk died 156 days after that meal; it was affected with tuberculosis of the cervical glands, lungs, and pleura. The 3 other kittens remained apparently well, and were killed over a year after the beginning of the experiment, and 305 days after the tuberculous meal. They all showed evidence of previous tuberculous infection, and in 2 of them I was able to find living tubercle bacilli in limited tuberculous lesions of the mesenteric glands and of the lungs. No appreciable difference was found between the kittens which had been exposed to garden air and the one which had been exposed to sewer air, and had received the same amount of tuberculous milk as that given to the garden air kitten.—August, 1909.

† By number of days (under Mortality up to January) is meant the time elapsed between the beginning of the experiment and the summing up or the death of the animal.

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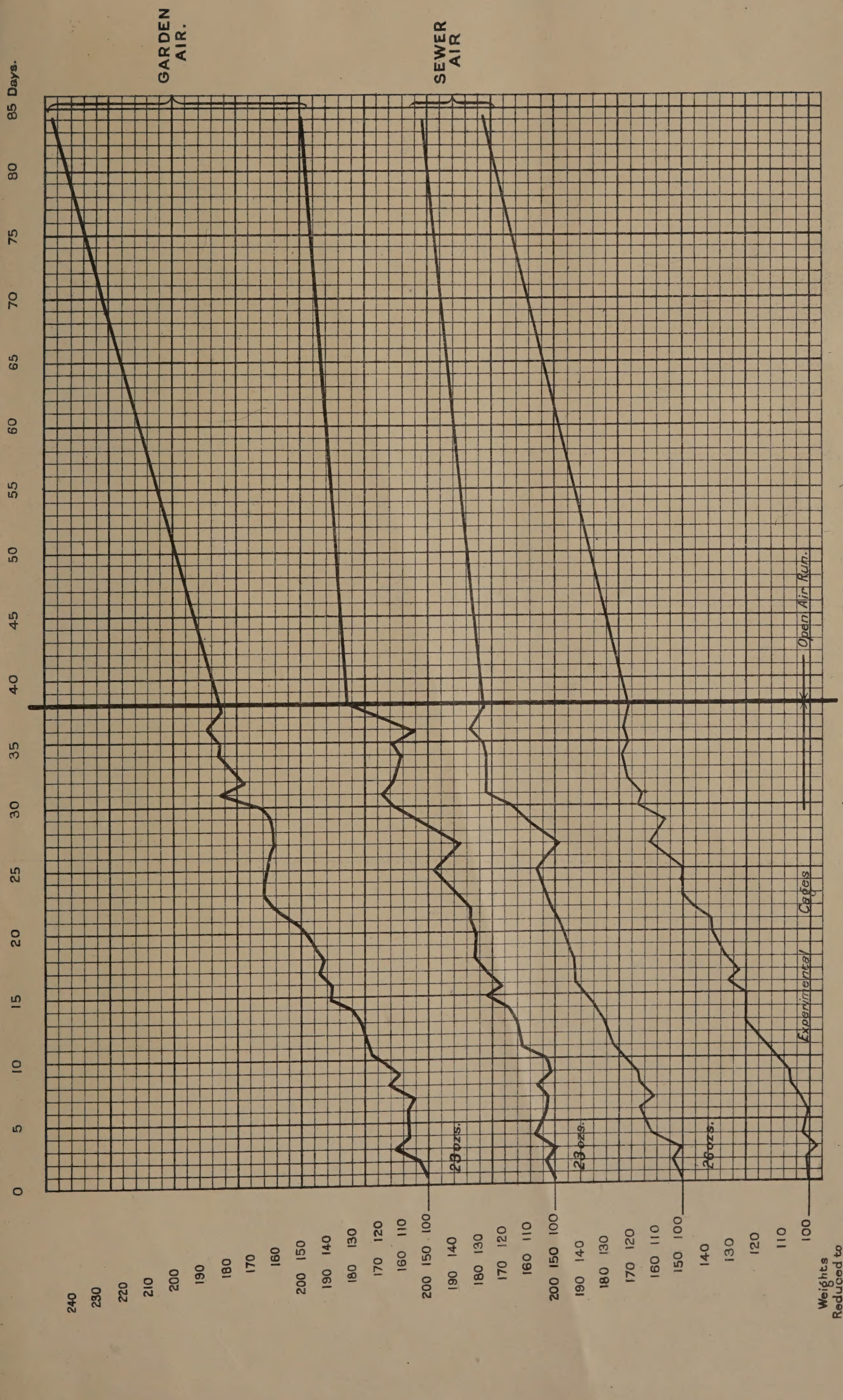
APPENDIX V *(Continued)*

DIAGRAM V.



Chart, showing daily weight (original weight assumed to be 100) of Kittens exposed simultaneously in cages to sewer air and garden air respectively, and the subsequent increase of weight when kept in an open air run.

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